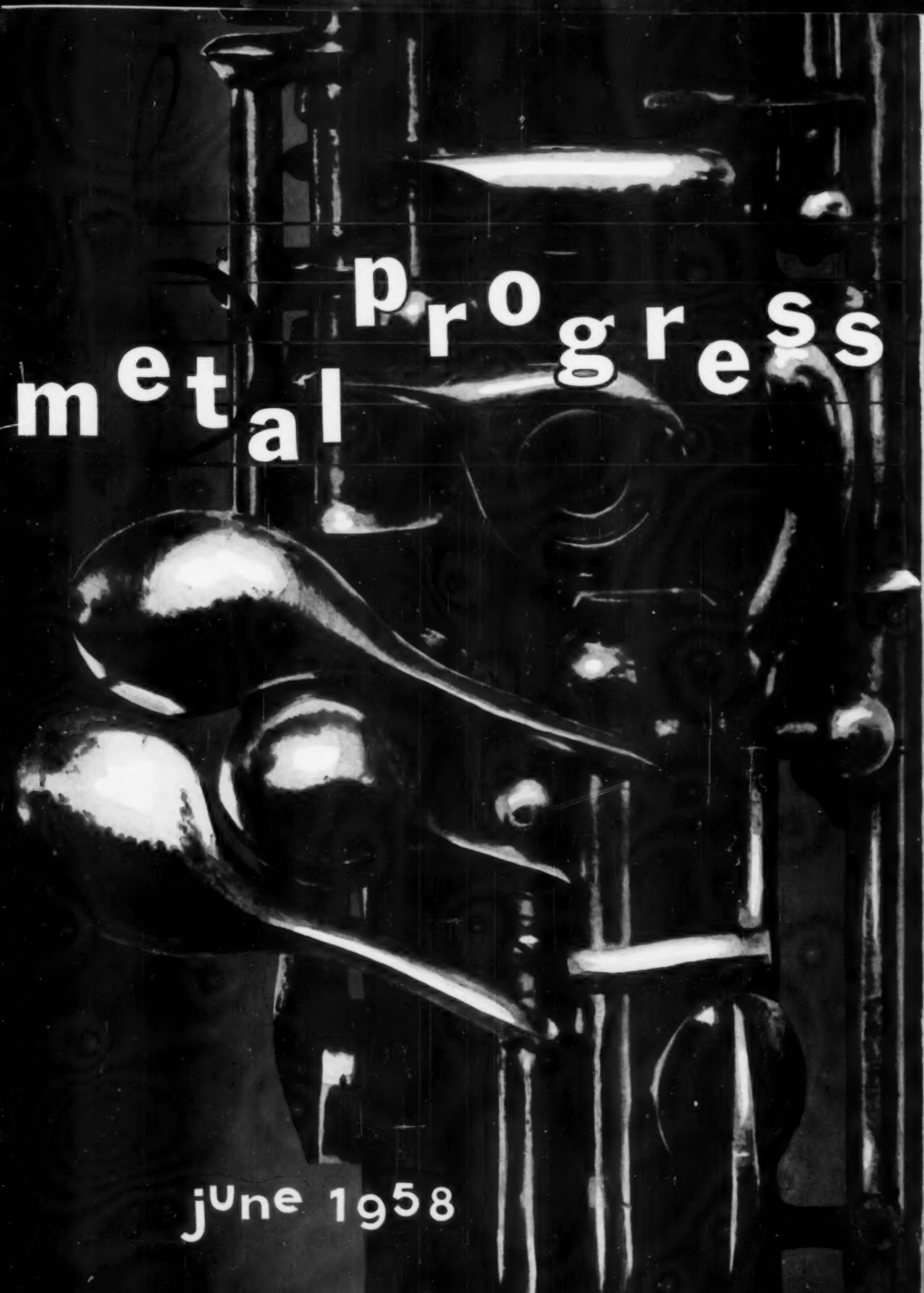
metal progress



june 1958

Metal Progress

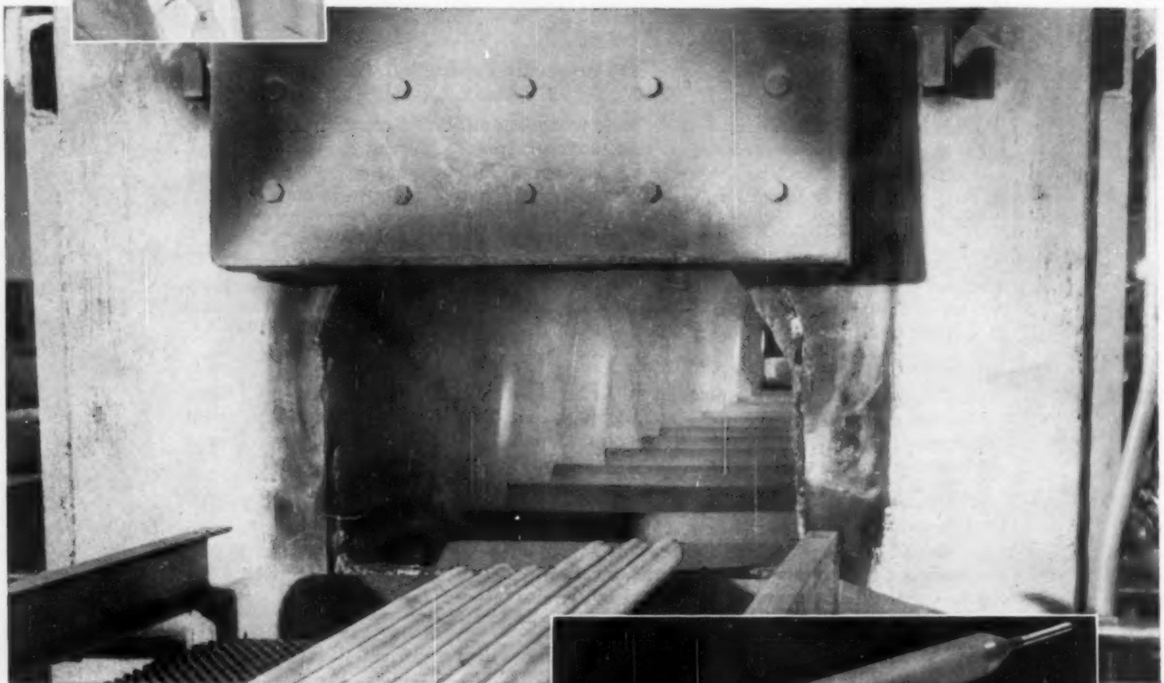
June 1958 . . . Volume 73, No. 6

Cover: Band Instrument Keys, by D. C. CRAWFORD; Prizewinner in Annual Competition at Cleveland Institute of Art

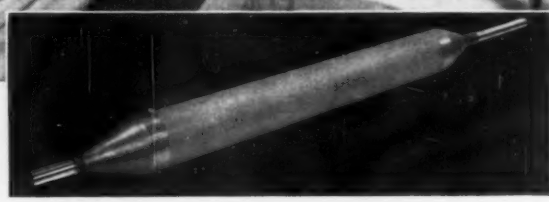
Table of Contents Continued on Page 3

Volume Index on Page 224

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



Damascus solution-anneals stainless steel welded tubing.



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Metallurgical company—Called in to help settle a debate between plant engineers and safety department about where to put a large NH_3 tank, Herb Kerr's experience helped influence final decision. Later Kerr put in a 16-hour day helping to unload first tank car and get equipment running properly.

Big chemical company—Problem: to recover NH_3 used as a solvent. Although customer preferred not to reveal full details of process, Kerr and George Cleek, Allied specialists, were able to devise for them an economical method for purification and recovery.

New manufacturer—Wanted to make household ammonia. Needed help to get started. Kerr conferred with Gar Ellis on laboratory test before suggesting equipment and recommending a supplier of an additive which was known to give the right degree of cloudiness.

Paper mill—was considering ammonium bisulfite pulping. Allied worked out complete plans for NH_3 equipment required. Herb Kerr checked with "Westy" Westlake of engineering research before proceeding on trip to be on hand at startup—and for another three days—to make sure operations would continue smoothly.

Chemical specialty company—Small, new at using NH_3. Bought some war surplus tanks, ran into problems, called Allied. "Zeke" Sziklas responded. Checked equipment they had, recommended additions, lined up contractor to install.

TECHNICAL SERVICE ON AMMONIA—**ALLIED** STYLE

Sure, you want your ammonia pure, but let's face it, ammonia specs are pretty much the same the industry over. Why, then, should you choose Allied over another supplier? Because you get—at no extra cost, and whenever you need it—the expert on-the-spot help of Allied technical service specialists.

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As I was saying...

IF YOU REALLY want to find out what's cooking, the thing to do is get away from home base and then get the news from your Girl Friday – so here's a doubleplay from Evelyn to Bill to You.

Dear Boss: It's been raining so the earth-moving contractors had to stop digging at the farm. They have been pulling top soil from the site and have a mountain of it piled sky-high. Everybody stops and wants to buy some. I suggest we package it in cellophane bags and sell it by the pound.

Architect Kelly reports the sewage system has been completed and accepted by the state inspector. The grading is now completed (I'm sending a picture) and Supt. MacKay expects to pour concrete for the footings this week.

Ah, yes, the contract for the geodesic dome (250 ft. in diameter, 103 ft. high – as though you didn't know) has been awarded to North American Aviation of Columbus, Ohio. I expect some morning to learn the company has attached a couple of G. E. jets to the dome and flew-de-coop away.

Dr. Lyman and Howard Boyer gave you a progress report on the new Metals Handbook. The new Volume I, "Properties and Selection of Metals", does not replace the '48 edition. It replaces in expanded form about 375 pages of the '48 edition. There were 192 contributors to that section of the old Handbook. There are more than 1200 men, working through 78 committees, contributing to the 1000 pages of material that will replace the 375 pages covered in the '48 volume.

The other volumes to be produced, one a year, are Vol. II, "Processing and Fabrication of Metals"; Vol. III, "Testing, Inspection and Metallography of Metals"; Vol. IV, "Phase Diagrams".

Now I understand why you do not expect to have the present volume returned as in the past.

Mr. Wells reports that the Southwestern Metal Show has closed the books and the space sale was very satisfactory; that the Cleveland Show (October '58) is maintaining a highly pleasing space-sale rate; that the requests for space at the Los Angeles Western Metal Show (March '59) are rolling in at a top rate. (*Continued on p. 6*)

Excavating Area for Lower Level of Headquarters Building. Retaining wall for approach drive in left background. View looking from back of property toward main road

As I was saying...

Mr. DuMond has the Southwestern program all cleared away and most of the contributions are already in. Preparations are being made to have all the panel material published and available for sale at a low price. Using the multilith reproduction method not only saves time but keeps the cost down.

The Metals Park Investment Club (all ASMers) had its first meeting in the office dining room at 5:30 last Friday but made no decision as to the growth stock to buy. (Ted DuMond is president, Pete Ford is vice-president, Marjorie Hyslop is secretary and Jim Hontas is treasurer-agent.) It's going to be lots of fun and I hope no one gets hurt. They are going to appoint a sergeant-at-arms. What does he do?

The place is almost deserted. Everybody is at Dallas for the big Show.

Marjorie Hyslop gave a talk at Ohio State Engineers Day, telling about A.S.M. research on documentation and literature searching. Big applause (led by A.S.M.-O.S.U. Tone Brasunas, no whistling permitted).

The A.S.M. Advisory Committee on Metallurgical Education met here this week. They saw the movie, "How Metals Behave", and gave it an enthusiastic okay. Mr. Bayless reports that the nine prints of that film are in use all the time. Five A.S.M. chapters have purchased copies of the film for local distribution.

M.E.I. had over 700 students at the last report. Two colleges want to use the lessons in their metallurgy courses. Switzerland, Germany, Spain and Brazil want to translate to native tongue.

Don't worry too much. It certainly is a responsibility to have two million dollars to spend for a building and for site preparation. Perhaps you should view the T.V. series, "The Millionaire". The people who get the million usally enjoy spending it and don't worry about time lost when it rains. They have no ulcers, so don't you open an ulcer department.

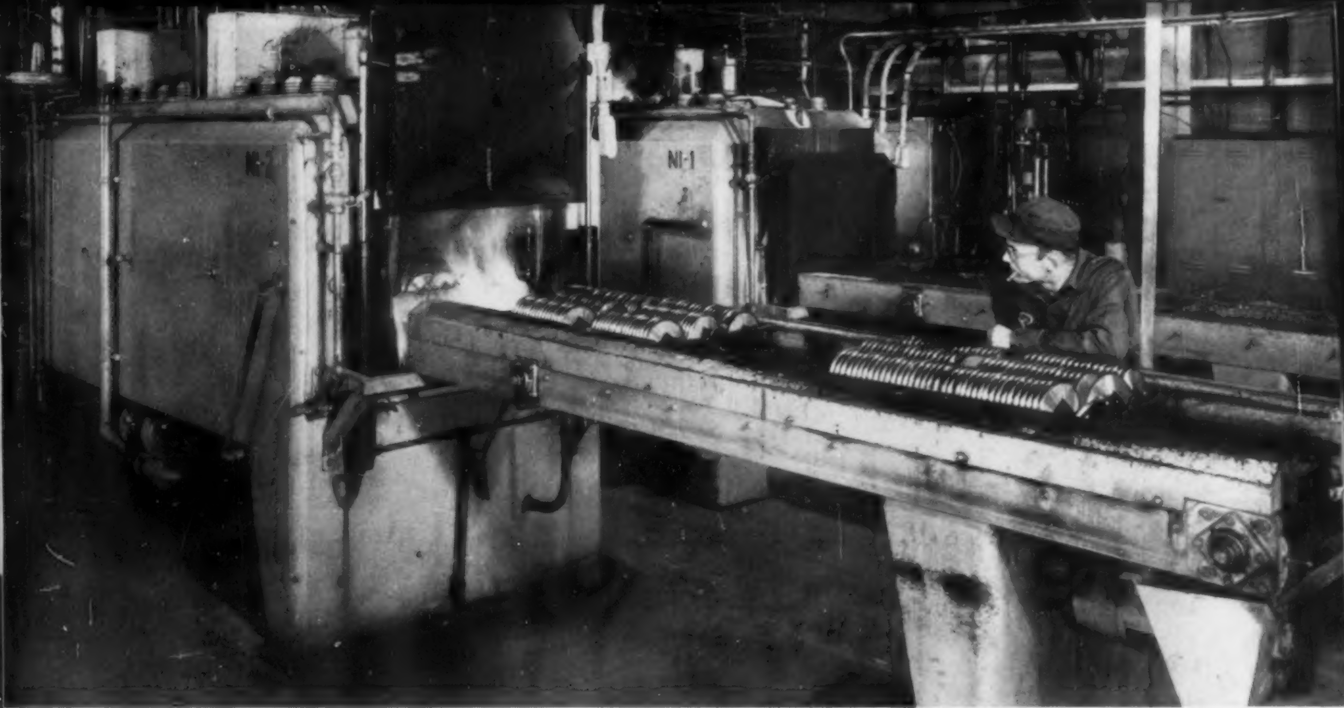
See you soon. Sincerely, EVELYN.

So there it is, good news, good advice. Perhaps I should view that T.V. feature. But the case is different. It's not my million, it's yours. I am just the P.A. for you, and I heard all P.A.'s have ulcers.

Cordially,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS



Two of six Ipsen Heat Treating Units used in Perfection's two Chicagoland plants

"...with Ipsen heat treating units, we get bright work, and increase production per man-hour."

Perfection Tool and Metal Heat Treating Co.

Don Petersen is president of Perfection Tool and Metal Heat Treating Company, one of Chicago's largest and best known custom heat treating organizations. To learn firsthand how and why Perfection uses semi-automated, controlled atmosphere, heat treating equipment, we had an interesting chat with Mr. Petersen. Here are his answers to our questions:

Q. Since 1951 you have purchased a number of Ipsen "straight-through" heat treating units. Why have you favored this equipment?

A. We were well pleased with the first Ipsen furnace we bought, and our customers were well satisfied with the quality of the work that came out of it. Since the end of World War II, there has been a much greater demand for atmosphere work, and, as this demand increased, we have purchased additional furnaces. We have four Ipsen units in our Hubbard Street plant . . . and two in our branch plant in Lombard, Illinois. All six units have two work chambers which make them ideal for preheating.

Q. What kind of work do you handle in your Ipsen equipment?

A. In the course of the average day we handle many, many different types of work . . . gears, screw machine parts, stampings, etc. We use your furnaces for carburizing, carbonitriding, neutral atmosphere hardening, and carbon restoration. The versatility of Ipsen furnaces is quite a selling point as far as we are concerned.

Q. Have you been able to increase production with this equipment?

A. Yes. With Ipsen equipment we have substantially increased production per man-hour. One reason for this is that quenching is automatic . . . and our operators do not have to handle parts in and out of the quench by hand.

Q. Apparently you like the automatic quench feature. Why?

A. Definitely. The automatic timing makes it easy to duplicate previous quenching results. We eliminate the element of human error in quenching.

Q. What about maintenance of your Ipsen equipment?

A. You have an excellent record on this count. We find that your equipment requires very little maintenance.

Q. What do your men think of Ipsen equipment?

A. Our men like your equipment because it's cleaner, cooler, and easier to operate. It takes less effort per pound of work treated.

Q. Has Ipsen equipment permitted you economy of floor space?

A. Yes. We find your equipment to be quite compact for the amount of work handled. In our Hubbard Street plant four Ipsen units are placed so the discharge ends converge on the same washing and degreasing unit. The entire installation occupies only 600 sq ft of floor space.

A brochure describing the type of Ipsen equipment used in the Perfection plants is available. Ask for your copy.

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Metal Progress

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Educational activities: Operates National, Western, and Southwestern Metal Congresses and Expositions; prepares and administers courses for Metals Engineering Institute for home, in-plant or American Society for Metals Chapter study.

Sylvania develops cast germanium and silicon discs for more efficient infrared detection systems

GERMANIUM AND SILICON LENSES, ground from optical blanks cast by Sylvania, are finding wider application in the infrared detection systems in today's missiles and aircraft. These semiconductor materials are transparent to wave lengths above 7 microns where other materials, such as quartz, are opaque.

Sylvania's Chemical & Metallurgical Division now offers cast discs of polycrystalline germanium in sizes as large as 8½ inches in diameter and 6 inches thick. Even larger sizes are being developed to meet the needs of detection system manufacturers. Cast silicon discs, too, are available for infrared use. Silicon, which weighs less than germanium, is finding growing acceptance in airborne systems. Other factors, such as the maintenance of infrared transmission characteristics at higher temperatures are of particular interest.

Through constant research and close cooperation with industry, Sylvania is continually improving its products to meet the needs of all areas of electronics. This is a basic reason why Sylvania has become a leading source for both silicon and germanium for all applications.

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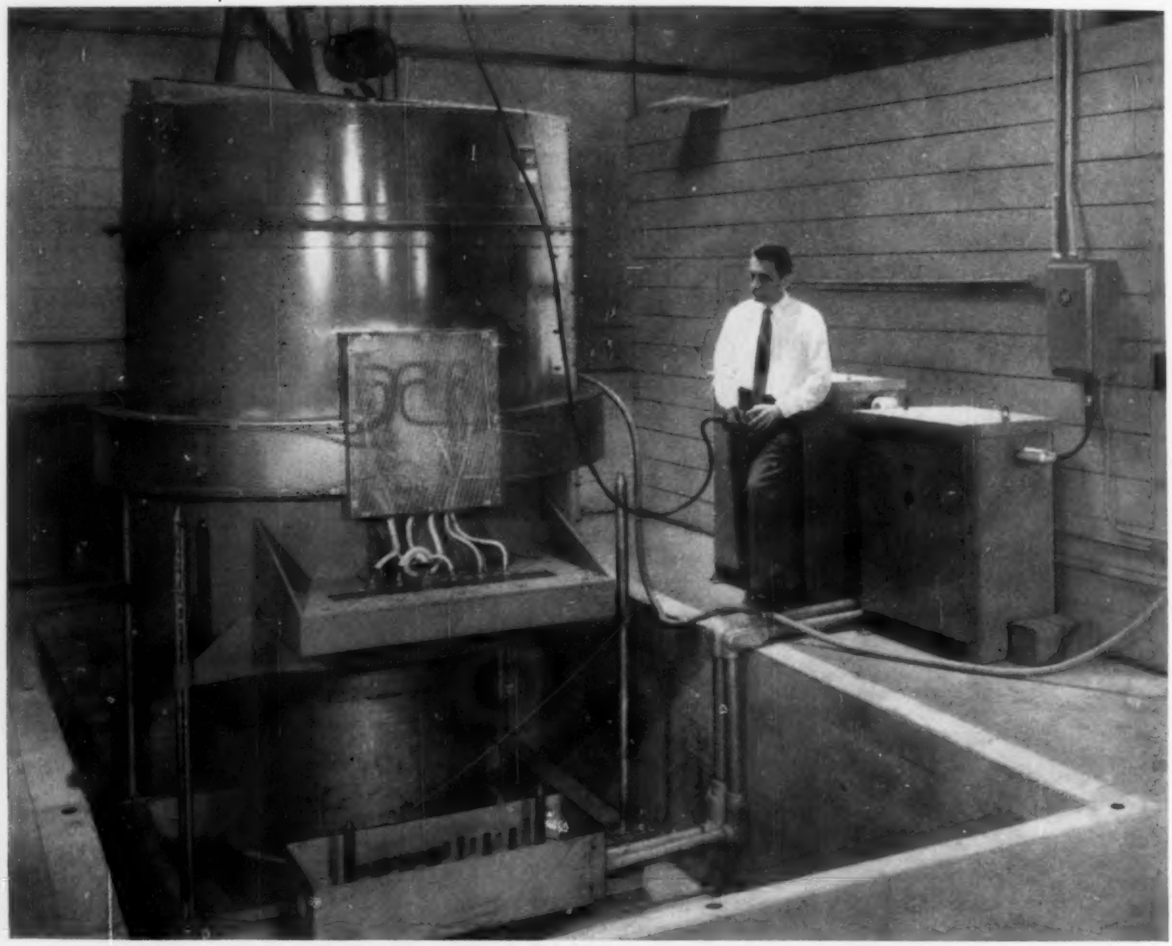


New Heat Treating Furnace Holds Vacuum or Atmospheres in its Inconel Retort

This new furnace heat treats parts up to 40 inches in diameter and 36 inches high . . . using either vacuum or controlled atmospheres and temperatures as high as 2250°F.

Pacific Scientific Company built it for Metallurgical Consultants, Inc. of Maywood, California.

Design of unit posed several metal problems

High temperature strength to withstand high vacuum. Resistance to oxidation. Resistance to nitriding. Ability to withstand the thermal shock of cooling rates as high as 50°F per second. Good formability, weldability, and machinability.

Those were some of the considerations that led Pacific and MCI to use versatile Inconel* nickel-chromium alloy for all major parts of the furnace . . . the retort itself, base sheathing, and work supports.

Inconel alloy is also used for the circulating fan that keeps temperatures uniform

Inconel alloy provides the high temperature strength, ductility and oxidation resistance called for. It also lends itself well to all forms of fabrication needed in designs for high-temperature furnace metal parts and fixtures.

Maybe you would like to see some of the many ways Inconel alloy improves service life of high temperature equipment . . . or some of the new types of equipment that have been developed with it. An Inco picture-booklet, "Keeping Costs Down as Temperatures Go Up" will do just this for you. And we'll gladly send you a copy.

*Registered trademark

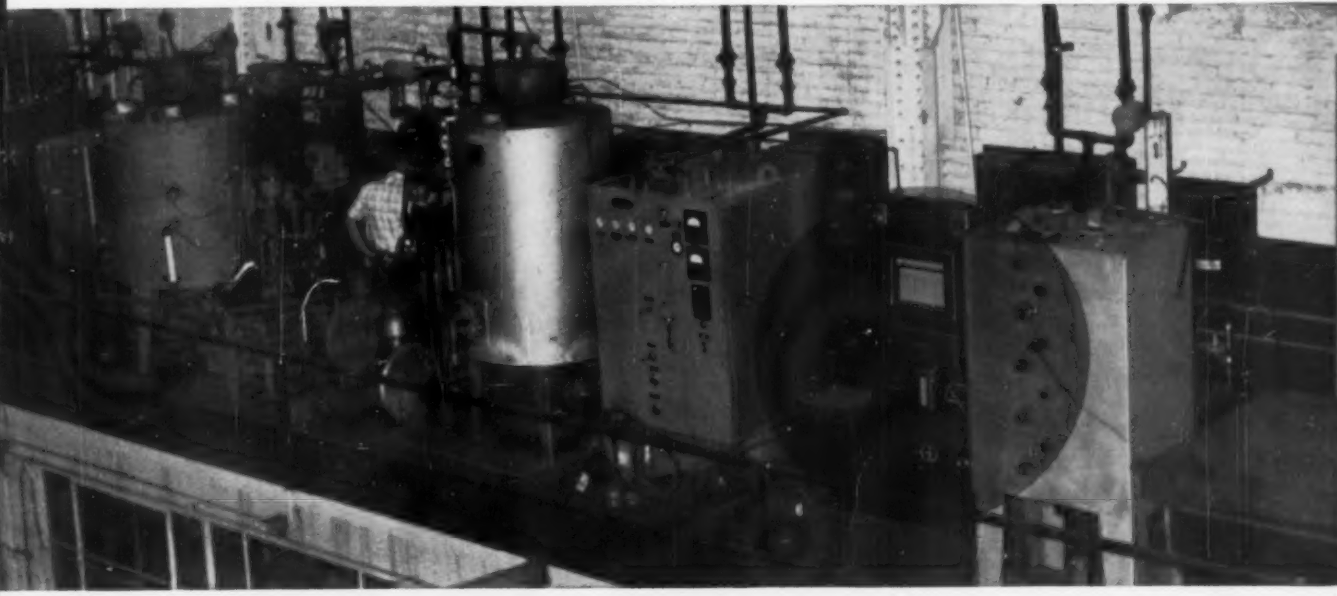
THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL ALLOYS

M-S-A® LIRA Analyzers help control dew point of furnace atmospheres

You can prevent damaging oxidation and change in carbon content of metal surfaces by measuring water vapor content with M-S-A infra-red analyzers



Typical installation shows M-S-A LIRA Analyzer calibrated for suitable dew point ranges to determine carbon potential of the furnace atmosphere.

Heating metals like steel, copper, brass, etc., generally makes them chemically active with the atmosphere in the furnace.

Such atmospheric furnace action may damage the surface of the metal. It may cause scaling by oxidation. Or change in surface carbon by carburization or decarburization.

To combat this quality control hazard, many metallurgists are holding the carbon range to much closer tolerances with dew point control by infra-red analysis. And they're using M-S-A LIRA Analyzers to do the job. Safely. Reliably. Accurately.

Since water vapor is such an ideal absorber of infra-red radiation, M-S-A LIRA Analyzers are extremely well-adapted for controlling the dew point of a furnace atmosphere.

There are a number of M-S-A LIRAs installed in annealing operations of strip steel and special carbon steels, and also in pure hydrogen atmospheres where hydrogen brazing is taking place.

Principle of operation for the M-S-A LIRA is simple. The gas sample passes through a sample cell through which an infra-red beam is directed. This direct beam measurement eliminates the problems usually encountered in such analysis: getting water vapor to react with some salt, or cooling it to cause a frost on a mirror, etc.

An MSA Instrument Specialist will be pleased to discuss your specific problems with you. Write for information regarding your particular problems of atmospheric analysis and control.

The entire assembly of the M-S-A LIRA Analyzer is mounted on a self-supporting panel. All adjustments are easily made from the front of the panel.

INSTRUMENT DIVISION

Mine Safety Appliances Company

Pittsburgh 8, Pennsylvania

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HARDNESS TESTERS • *WORLD'S STANDARD OF ACCURACY*

ACCO for Better Values

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No matter what your hardness testing requirements are, there's a WILSON "ROCKWELL" instrument to do the job. Choose from this complete selection of hardness testers:
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Superficial—for extremely shallow indentations.
Twintester—combines functions of "ROCKWELL" and "ROCKWELL" Superficial testers.
Semi-Automatic (manual feed) and Fully Automatic—for automatically classifying tested pieces as CORRECT, TOO HARD, or TOO SOFT—at test rates up to 1000 pieces per hour.
Special Machines—for testing large objects, obtaining internal readings, and other unusual applications.

ALL WILSON "ROCKWELL" hardness testers provide these advantages:
Accurate performance—precision built, with exact calibration, for consistently correct results.
Long life—durable as a machine tool.
Easy operation—even an unskilled operator can get perfect readings. All controls conveniently grouped.
Easy maintenance—interchangeable mechanisms, with spindles mounted on oil-less bearings.

DIAMOND "BRALE" PENETRATORS ... perfect testing every time

A perfect diamond penetrator is essential to accurate hardness testing. Since one point of hardness on the "ROCKWELL" scale represents only 80 millionths of an inch penetration—only 40 millionths on a Superficial tester—the slightest imperfection will cause a false reading.

Only *perfect* Wilson Diamond Brale Penetrators are sold. Each diamond is flawless, with no chips or cracks. It's cut to an exact shape. Microscopic inspection of every diamond—one at a time—assures this perfection—and assures you of accurate hardness testing every time.

TUKON TESTER ... for precision MICRO & MACRO testing

The TUKON Tester measures extremely shallow indentations. It's used, for instance, by manufacturers of watches, hairsprings, needles, and fine wire. Laboratories use the TUKON for tests on individual crystals or particles of microscopic size. Producers of coatings, film, ceramics, and many other materials have made good use of the TUKON.

Three models are available to meet your individual requirements. TUKON Testers use both the Knoop and 136° Diamond Pyramid Indenter. Each TUKON Tester is a self-contained hardness testing instrument— no accessory equipment is needed. Knife edges and levers of fixed length are used throughout for application of exact load and freedom from internal friction.

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A wide variety of bulletins describes the many instruments, accessories, and services Wilson offers. Write for your choice:
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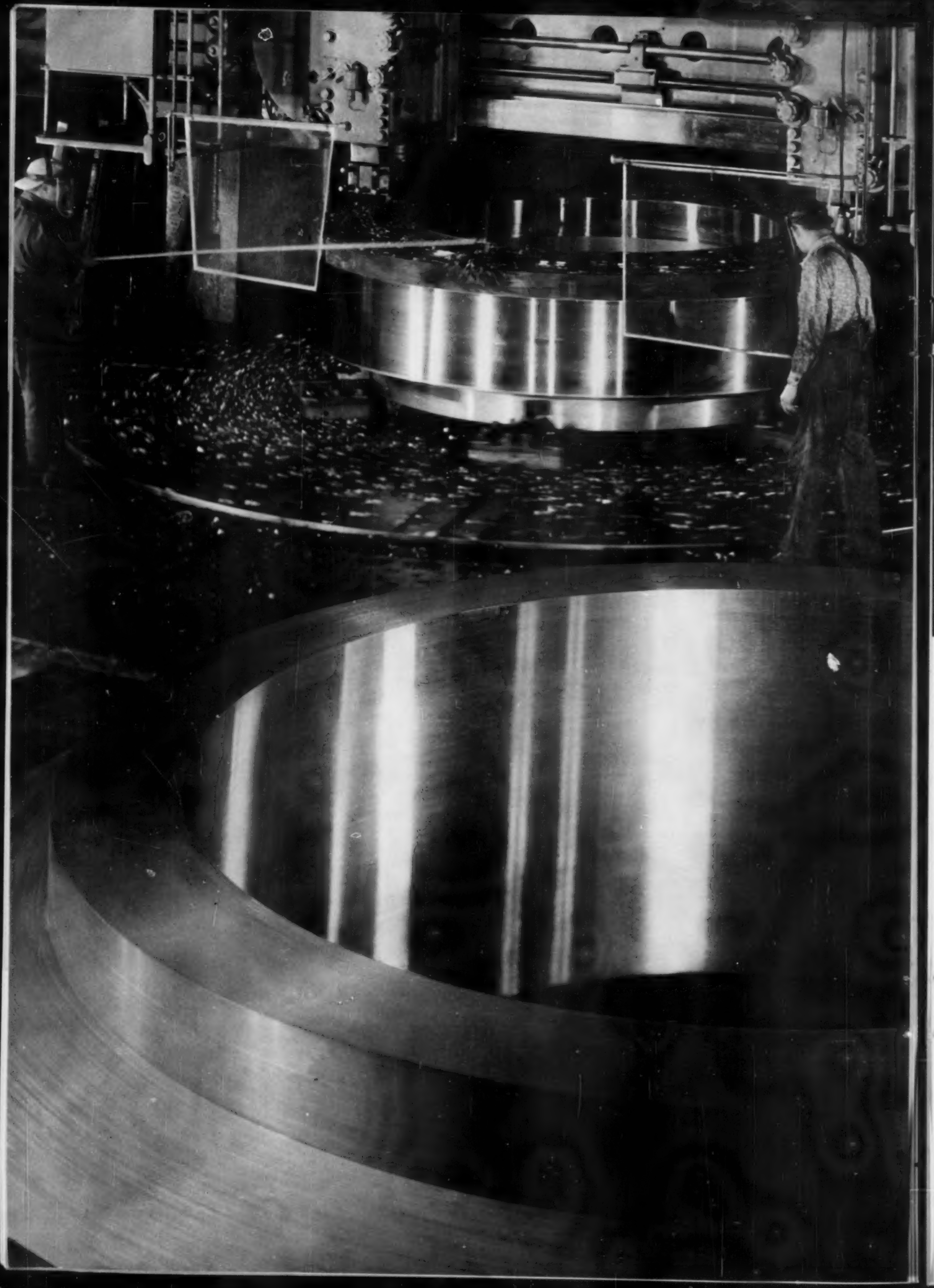

Father and son total 70 years machining steel

At the U. S. Steel Homestead Forge Shop, you find a lot of men who carry on in the shoes of their fathers. Gus Seitz's father was a Journeyman Machinist for 30 years before he retired. Gus started in the shop when he was 16, worked as an apprentice, Journeyman Machinist, Inspector. After six years in Production Control, he moved up to General Foreman, a post he has held for 10 years. With 40 years of machining experience behind him, Gus supervises a staff of 256.

His most important job: see that the work is carried out to the customer's specifications, *on time.*

The forgings in the picture illustrate some of the scheduling problems that Gus has to solve. These are closure head flanges for a nuclear reactor—130" OD, 88" ID and 35" high. Ingots were cogged, upset, punched and forged over a mandrel. Then they received the preliminary machining. Next came a quench-and-temper heat treatment to meet the physical properties needed by the reactor builder. Then followed about 10 days of testing for microstructure, tensile strength and ductility. Finally, the forgings were scheduled back onto the 20-foot vertical boring mill for final machining.

With men like Gus Seitz riding herd on your USS Quality Forging order, you can rest assured that money won't buy a better piece of steel. U. S. Steel has the men, the know-how, the equipment and steel to turn out forgings for the most critical service, and we're eager to help you solve your forgings problems. Write for our free 32-page booklet on USS Quality Forgings. Send your requests to United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa. *USS is a registered trademark*

USS

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
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United States Steel Export Company

United States Steel

ELECTRONIC and ULTRASONIC quality control of MUELLER rod, tube, fabricated parts and

Every practical electro-mechanical testing device available to industry today is used by the Mueller Brass Co. to maintain Positive Quality Control during each manufacturing operation. From the first stages of alloying, spectroscopic analysis is used to maintain exact alloy composition so that they are precisely as specified. Ultrasonic test equipment is utilized in the non-destructive testing of extruded brass and bronze rod, copper tube, forgings and fabricated parts. In machining and finishing operations, statistical quality control is employed to eliminate the effect of possible human error. These quality controls are all designed for one purpose . . . to give you complete "product protection."

•

Copper base alloy rod is examined by a trained operator with the aid of an ultrasonic reflectoscope. Through electronic circuitry, ultrasonic echoes are translated on a cathode ray tube. Any internal flaws are readily apparent. Both rod and tube are tested by this method, which is just one of many Positive Quality Control checks used by the Mueller Brass Co.

Through ultrasonics, the immerscope (Left) locates internal defects, and has exceptional versatility for examining intricately shaped parts, such as the forging being checked in this photo. When testing, a transducer, located at the bottom end of the search tube, is electronically actuated to produce from 2.2 to 25 million cycles per second. Ultrasonic echoes are reflected back to the transducer from the material, indicating any defects that may be present. Limits may be pre-established and the sound findings are visually recorded on the cathode tube. This is another instance of Positive Quality Control in action.

For whatever you make...

N-A-X® HIGH-TENSILE STEEL

BUILDS IN STRENGTH WITH LONGER LIFE

Today's emphasis on fast mechanized freight car loading and unloading brings the superior qualities of N-A-X HIGH-TENSILE steel into sharp focus.

For boxcar flooring, increased mechanization means bigger, heavier and faster moving lift trucks, added abuse from still more weight concentration. For gondola flooring, increased mechanization means still more load impact and abrasion to go with the deteriorating effects of constant exposure to weather.

N-A-X HIGH-TENSILE steel solves these troublesome problems like none other. Used in Stran-Steel Corporation's famous N-S-F®, nailable steel flooring, N-A-X HIGH-TENSILE builds in extra strength, adds longer life. And top resistance to impact and atmospheric corrosion, plus ready weldability, makes N-A-X HIGH-TENSILE exceptionally suited to the special needs of railroad equipment manufacturers and railroads alike. No wonder sixty-three of the nation's leading railroads have ordered N-S-F for their freight cars.

CHECK THESE IMPORTANT ADVANTAGES FOR YOUR JOB:

N-A-X HIGH-STRENGTH steels—both N-A-X HIGH-TENSILE and N-A-X FINEGRAIN—compared with carbon steel, are 50% stronger • have high fatigue life with great toughness • are cold formed readily into difficult stampings • are stable against aging • have greater resistance to abrasion • are readily welded by any process • offer greater paint adhesion • polish to a high luster at minimum cost.

Although N-A-X FINEGRAIN'S resistance to normal atmospheric corrosion is twice that of carbon steel, N-A-X HIGH-TENSILE is recommended where resistance to extreme atmospheric corrosion is important.

For whatever you make, from steel shop boxes to steel freight cars, with N-A-X HIGH-STRENGTH steels you can design longer life, and/or less weight and economy into your products. Let us show you how.

◀ *Here again N-A-X HIGH-TENSILE steel proves its ready weldability. To manufacture Stran-Steel Corporation N-S-F®, nailable steel flooring, no less than eight separate welds between each two channels are required.*

Tough N-S-F®, nailable steel flooring of N-A-X HIGH-TENSILE, has already won wide acceptance with leading railroads everywhere. So much so, in fact, that more than 50% of all new boxcars now being built are ordered with it.

This typical modern fork-truck with its giant newsprint roll weighs a whopping 5,500 pounds! N-A-X HIGH-TENSILE takes even this kind of concentrated abuse easily, lasts for the life of the car.

N·A·X®
HIGH-STRENGTH STEELS

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☐ Please have your representative contact me.

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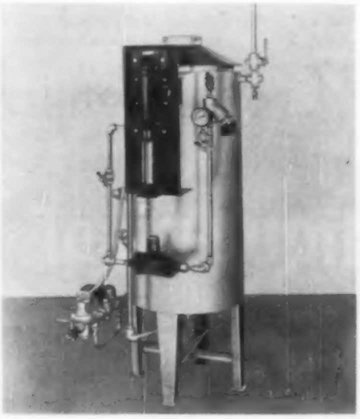
Company________

Street________

City________ Zone____ State________

Atmosphere Generators

Surface Combustion Corp. has announced three new dissociated ammonia atmosphere generators. The gas generators will have 250, 500 and 800 cu. ft. per hr. capacity. Residual ammonia content is less than 0.05% and dew point is −40° F. The generator



consists of a reaction tube, filled with a fast reacting catalyst. The reaction tube is suspended in a heating chamber and heated by a gas burner that encircles the bottom of the tube and fires vertically into heating chamber.

For further information circle No. 1185 on literature request card, page 48-B.

Saw

A circular cold saw for aluminum alloy billets has been announced by Loma Machine Mfg. Co. The hydraulically operated saw will cut aluminum alloy billets up to 21 in. square or 23 in. round. The machine is equipped with a 66-in. diameter sawblade operating at 6000 ft. per min. The machine

features a tilt arm, and the cut is effected through a downward movement of the sawblade. Complete automation is obtained by operating the saw in conjunction with billet handling equipment.

For further information circle No. 1186 on literature request card, page 48-B.

Hard Surfacing

A new hard surfacing powder with a high tungsten carbide content has been announced by Kennametal, Inc. It is applied to steel parts by metal spraying techniques. Irregular shapes and flat surfaces can be coated—the size and shape being limited only by accessibility required by the spraying equipment. After Kenspray is applied. the part is heated by an oxyacetylene torch or in a furnace to fuse the hard surfacing deposit to the base metal. Surface coatings can be controlled from 0.010 to 0.090 in. in thickness. The tungsten carbide content of Kenspray provides wear resistance and high hardness. Sprayed surfaces cannot be machined but can be ground with diamond or silicon carbide wheels where close tolerances are required.

For further information circle No. 1187 on literature request card, page 48-B.

Colored Stainless Steel

A new coloring process for stainless steel has been announced by Electro Metallurgical Co. Parts can be severely formed after coloring without impairing the surface, and large parts such as architectural panels can be processed. At the present time, only black is being produced commercially, but ultimately a range of colors will be available. The Permyron process involves applying the pigment in a vehicle to prepared surfaces by such methods as spraying or roller coating, and processing under controlled temperature and atmosphere.

For further information circle No. 1188 on literature request card, page 48-B.

Induction Heating

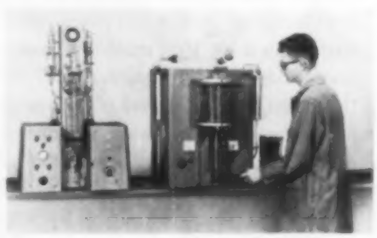
The addition of a dual frequency generator to its line of high-frequency induction heating units has been announced by Lepel High Frequency Laboratories. This generator is rated at 10 kw. of output power. The lower frequency range is 250 to 600 kc.; the higher frequency range is ap-

proximately 2 to 5 megacycles. The megacycle tank circuit components are located in the lower portion of the cabinet and the standard frequency tank circuit components in the smaller cabinet on the top. Both circuits use the same oscillator tube and d.c. power supply.

For further information circle No. 1189 on literature request card, page 48-B.

Oxygen Analysis

A new method for the determination of oxygen in steel, titanium, tungsten and other metals has been



announced by Laboratory Equipment Corp. The new method which uses the Leco conductometric oxygen analyzer

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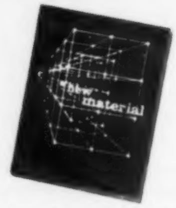

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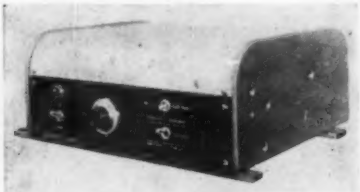
is capable of producing complete oxygen analyses in 5 min. with an apparatus range of 0 to 0.035% oxygen on the basis of a 1 g. sample. Sensitivity of the instrument is 0.0002% oxygen.

For further information circle No. 1190 on literature request card, page 48-B.

Zone Melting

Zone melting apparatus, for preparation and study of pure materials in solid state research and for the pro-



duction of semiconductor devices, has been announced by Research Specialties Co. The device provides the necessary mechanical apparatus for linear motion of sample heaters and can be used in a variety of ways for zone refining, zone leveling, and crystal pulling. The drive unit, with maximum travel of 4 ft., may be obtained by itself for installation as the slow speed element in any zone refining or crystal pulling system; or it may be obtained as an integral part of a zone melter assembly having a rigid bed and smooth ways for 26 in. excursion of a traveling carriage. The 7½ by 14 in. carriage is designed with several sets of slots for placement of heaters as needed by the user.

For further information circle No. 1191 on literature request card, page 48-B.

Heat Treat Baskets

Aluminum and Architectural Metals Co. has announced furnace baskets and fixtures made of RA330. Both bar and corrugated-type baskets will withstand temperatures of 1500 to 1800° F. in carburizing or carbonitriding atmospheres.

For further information circle No. 1192 on literature request card, page 48-B.

Quenching

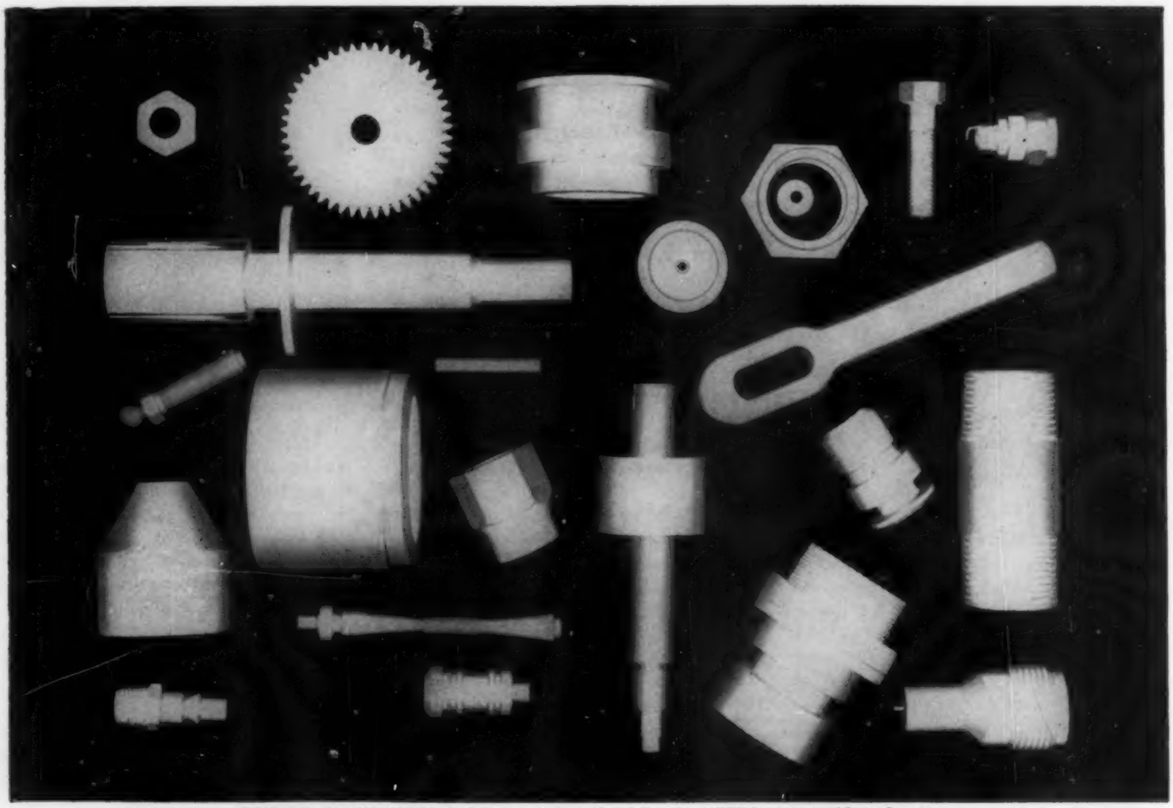
The Gleason Works has announced a new quenching machine for handling and quenching heated gears and other round, flat and cylindrical parts. Special features include the ability to handle the parts quickly from the furnace to quench and the introduction of a pulsing and flexing cycle. The workpiece is held between contact rings for pulsing, flexing and an initial quench, during the period of time when the critical changes occur. These

changes are nearly completed when a temperature of about 700 to 900° F. has been reached. The workpiece is then loaded onto a conveyor belt that moves slowly around the tank, under the oil, until the part is cooled and reaches the discharge elevator.

For further information circle No.1193 on literature request card, page 48-B.

Radiography

A cobalt 60 radiographic unit has been announced by Picker X-Ray Corp. The Cyclops provides facilities for radiographing heavy steel cast-



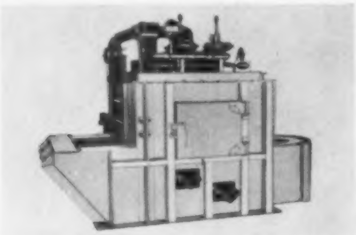
ONE OIL, MANY METALS. Moderately priced Sunicut 5534 gave uniformly excellent results in the machining of this wide variety of top-quality steel parts.

ings, weldments and other steel products up to 10 in. thick with 1 and 2% radiographic sensitivity. It radiates energy equivalent to the 2 to 3 million volt X-rays. Its cobalt 60 radioactive source is contained in a steel-jacketed lead sphere flexibly mounted so the beam can be aimed in any direction. To let out the radiation, a shutter is opened by remote electrical control.

For further information circle No. 1194 on literature request card, page 48-B.

Melting-Holding Furnace

New combination melting and holding furnaces in capacities of 1200 to 5000 lb. have been announced by Sunbeam Corp. The furnaces are gas-fired



and automatic temperature controlled. They may be used for die casting, permanent mold casting or sand casting of aluminum. Rejects and back scrap can be charged back on the sloping hearth, eliminating any contamination of the inside of the furnace with inserts. Furnaces can be built with or without tap holes for complete draining. A bridged ladle-out well allows constant chlorination and a clean supply of metal.

For further information circle No. 1195 on literature request card, page 48-B.

Constructional Steel

New guaranteed strength minimums for USS T-1 steel have been announced by U. S. Steel Corp. The minimum yield strength has been increased from 90,000 to 100,000 psi. and minimum tensile strength from 105,000 to 115,000 psi. Tensile strength maximum remains at 135,000 psi. T-1, low-carbon, quenched and tempered alloy steel may be used now at higher design stresses.

For further information circle No. 1196 on literature request card, page 48-B.

Dew Point Measurement

Illinois Testing Laboratories has announced a new instrument for measuring the dew point of gases which are under pressure, such as in gas pipe lines, compressed air lines, instrument air lines and bottled gas. It operates over a range from room

temperature to $-80°$ F. The instrument incorporates a by-pass valve and rupture disks as safety devices to protect the instrument.

For further information circle No. 1197 on literature request card, page 48-B.

Leak Detectors

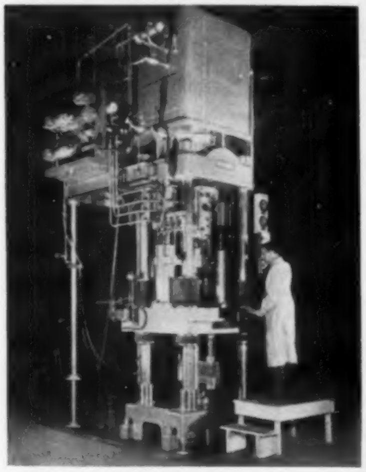
A new line of halogen-type leak detectors has been announced by General Electric's Instrument Department. Each of the new models can locate leaks as small as 10^{-8} cc. per sec.—leakage of less than 1 oz. of escaped gas every 100 years. The detectors use any halogen compound tracer gas. The gas can be introduced

as a tracer into practically any system that does not already contain a halogen gas. They are designed for 120 to 240-volt, 50 to 60-cycle operation.

For further information circle No. 1198 on literature request card, page 48-B.

Powdered Metal Presses

A new series of hydraulic powder metal compacting presses of simplified design has been announced by the Press Div. of F. J. Stokes Corp. The new series of presses offers units with pressing capacities of 100, 200, 300 and 500 tons. They are single-acting presses with the upper punch motion delivering the full pressure of the

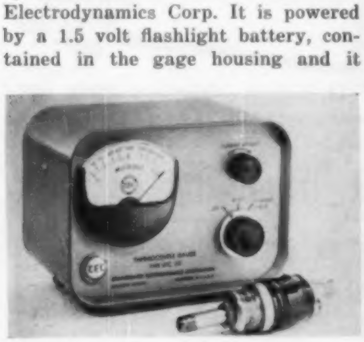


rated capacity by means of the downward stroke of the hydraulic ram, and a hydraulically supported die table which provides adjustable upward resistance to the motion of the upper punch. This movable die table provides the equivalent of pressure from below for simple straightwall parts. The bottom punch, which extends up into the die is fixed. A 300-ton model is shown above.

For further information circle No. 1199 on literature request card, page 48-B.

Vacuum Gage

A new battery-operated thermocouple vacuum gage has been announced by the Rochester Div. of Consolidated Electrodynamics Corp. It is powered by a 1.5 volt flashlight battery, contained in the gage housing and it

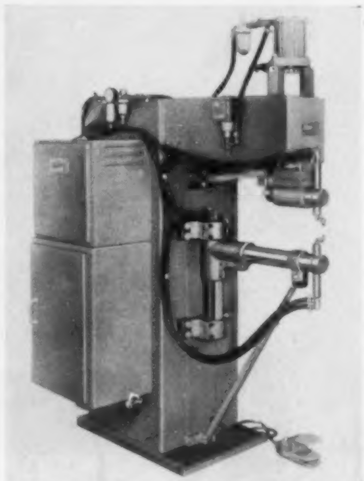


covers the range from 0 to 1000 microns Hg on one nonlinear scale, with 5 microns the smallest indicated marking. Recalibration is accomplished by setting the indicator at zero when the pressure in the system is below 1 micron. The GTC-110 gage is 4⅞ in. high, 6⅛ in. wide, 3¾ in. deep and weighs 4⅛ lb.

For further information circle No. 1200 on literature request card, page 48-B.

Spot Welder

Alphil Spot Welder Mfg. Corp. has announced a resistance spot welder specially designed for the sheet metal, wrought iron and wire fabricating industries. The roller-bearing ram permits precision alignment of the work together with application of positive pressure. An independent air valve



brings the ram down for fine electrode adjusting. Current capacity is 75 kva. and temperatures adequate for welding 16-gage commercial aluminum and 7-gage cold rolled steel are attainable. Maximum short circuit secondary amperage is 26,000. A second-stage foot switch allows selection of either manual or automatic operation.

For further information circle No. 1201 on literature request card, page 48-B.

Furnaces

A prepiped radiant roof panel for rebuilding and conversion of industrial processing furnaces has been announced by J. A. Kozma Co. It consists of radiant cup-type burners mounted in a one-piece refractory tile casting. Connection of a gas supply line and an air line can be accomplished quickly. The roof panel can be suspended by integral ⅝ in. steel tie rods attached to the reinforced refractory cover plate. Companion arches are available for use with the radiant panels as front walls in slot-type

furnaces or as curtain walls in continuous furnaces.
For further information circle No. 1202 on literature request card, page 48-B.

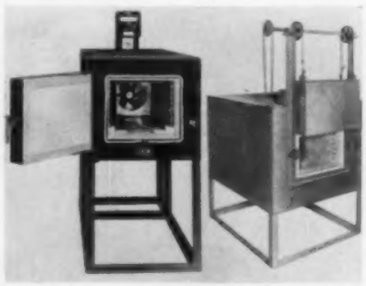
Thickness Gage

A new wet film thickness gage has been announced by Nordson Corp. It is capable of measuring wet film ranging

from ½ to 20 mils of all paints, coating oils, adhesives, plastics and other finishing materials. The only moving part, a face plate, is rotated to adjust to the estimated wet film thickness.
For further information circle No. 1203 on literature request card, page 48-B.

Heat Treating Furnaces

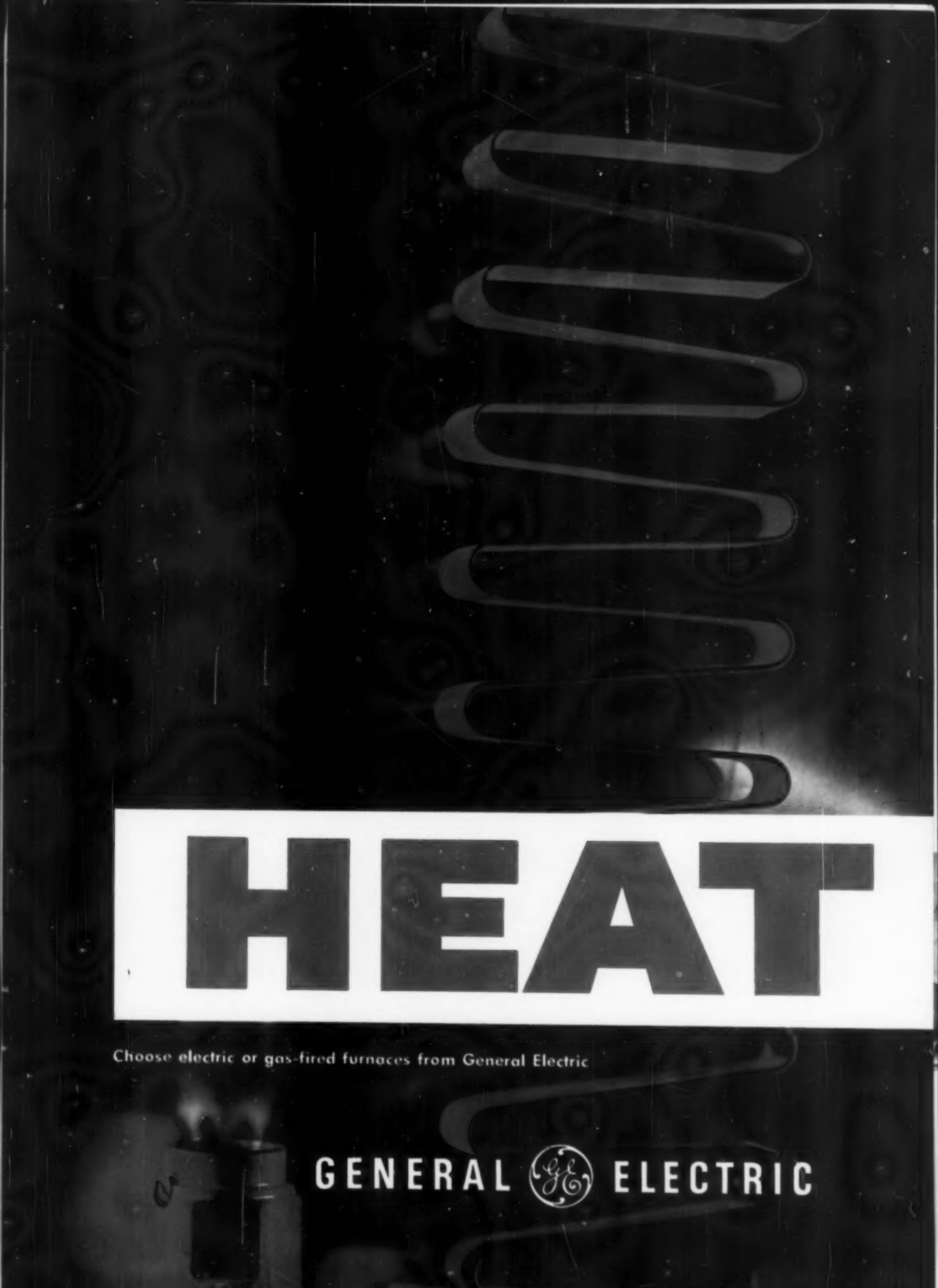
Lucifer Furnaces, Inc., has announced two new electric heat treating furnaces. The Series 5055 (right) is a box-type furnace for hardening, annealing, drawing and preheating operations. It is available in four



models with heat ranges to 2000° F. The Series 4055 (left), forced-air furnace, is designed for tempering, drawing and heat treating aluminum. It is manufactured in nine standard models with operating temperatures to 1250° F.
For further information circle No. 1204 on literature request card, page 48-B.

Tool Steel

Crucible Steel Co. of America has announced a new tool steel with shock resistance and high-toughness at high-hardness levels. LaBelle HT is a low-alloy steel for use as shear blades, impact extrusion tools, cold heading dies and punches, and coining, and striking dies. LaBelle HT averaged 25,000 pieces in an aluminum extrusion application, 60,000 pieces as a cold heading punch and 113,000 to 130,000 pieces as cold heading dies.
For further information circle No. 1205 on literature request card, page 48-B.


HEAT
Choose electric or gas-fired furnaces from General Electric
GENERAL ELECTRIC

HEAT

1. BRIGHT ANNEALING furnace reduced many machining costs.

FROM GENERAL ELECTRIC CAN CUT COST, IMPROVE QUALITY OF YOUR PRODUCT, TOO

General Electric furnaces speed production, cut rejects, reduce maintenance costs in hundreds of processing jobs. Your decision to call G-E heat experts *now* can save you money today and for years to come.

Nearly any product, like those shown at left, can be made better and at less cost through a heat processing modernization plan set up by General Electric. The savings you realize can pay off the initial cost of the system in two to three years—you get extra profits in years to come, cost-savings and a more saleable product today.

Here are four examples of the results achieved through the use of G-E heat processing equipment (pictured below):

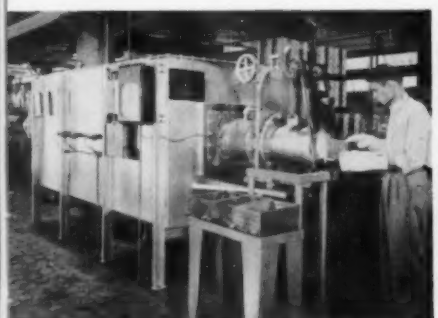
1. SAVINGS OF 25 TO 50% in the manufacture of high quality stainless steel parts were realized as a result of bright annealing in General Electric furnaces in a Midwest heat treating plant. Two years of high-speed processing with virtually no maintenance and with low operating cost have resulted in high investment return and improved products.

2. PICKLING WAS ELIMINATED by bright brazing stainless steel parts in a General Electric semi-continuous tubular retort furnace. Bright, shiny parts of high quality are now produced in less time, at lower cost.

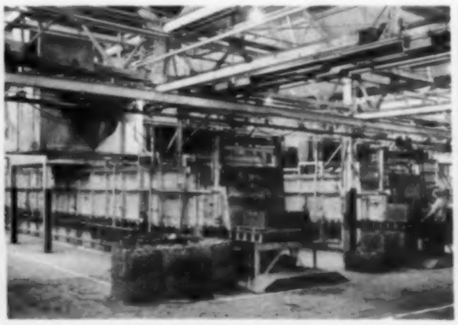
3. 75% SHORTER ANNEALING CYCLES—malleable-iron annealing with automatically-controlled General Electric roller-hearth furnaces cut cycle from 4 days to 48 hours, cut man-hours 40% for a Midwest concern. Straight-line, continuous annealing boosted process rate to 32 tons of high-quality castings every day and eliminated heat-up and cool-off time formerly required by old oil-burning furnaces.

4. 300% FASTER HARDENING of transmission components is made possible by a General Electric electronic induction heater in an automotive plant. Parts enter one end, progress on rollers to the other end and are flipped over for hardening of the reverse side at the rate of one every six seconds. Higher quality products are produced.

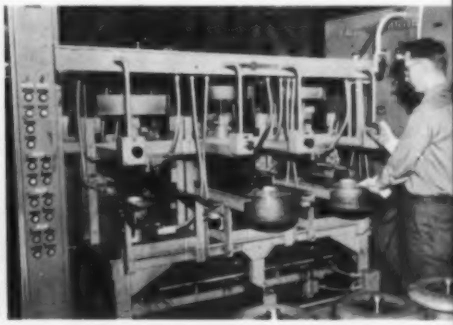
You can achieve results like these with a heat modernization system planned by General Electric to fit your needs. If you suspect that obsolete heat processing equipment is robbing you of profits, call your G-E Apparatus Sales Office. A qualified Heating Specialist will quickly figure your present costs, and your potential savings. Why not call today? Section 721-16, General Electric Company, Schenectady 5, N. Y.



2. BRIGHT BRAZING FURNACE eliminated all pickling costs.



3. CONTINUOUS ANNEALING FURNACE cut malleable-iron annealing cycle 75%.



4. INDUCTION HEAT TREATING increased production by 300%.

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APPLICATION and EQUIPMENT new literature

1207. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber*

1208. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

1209. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1210. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1211. Alloys
New 8-page pocket-size Booklet No. J4 on low-melting-temperature alloys. 63 applications in the metal field. Descriptions and physical properties. *Cerro de Pasco*

1212. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1213. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

1214. Aluminum Extrusions
Catalog of stock extrusion dies. *Jarl Extrusions*

1215. Aluminum-Iron Alloys
New Technical Data Bulletin IND-18 on aluminum-iron alloys for applications requiring high quality, soft magnetic materials. *General Plate Div., Metals & Controls Corp.*

1216. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

1217. Ammonia
8-page booklet on uses of dissociated ammonia in industry. Dissociation process and applications in bright annealing, furnace brazing, powder metallurgy, bright hardening. *Armour Ammonia*

1218. Ammonia
New 69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography. *Nitrogen Div.*

1219. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever Co.*

1220. Atmosphere Equipment
New Bulletin No. I-101 on carbon dioxide removers. Design features, data chart, operation. *C. M. Kemp*

1221. Atmosphere Furnace
4-page bulletin on automatic continuous heat treating furnace. Operational advantages, principle of operation, capacity, construction. *American Gas Furnace*

1222. Atmospheres
New 6 and 4-page bulletins on ammonia storage units and nitrogen generator. *Hamler Industries, Inc.*

1223. Automatic Controls
New 60-page Catalog No. 858 on automatic controls for heating and industrial applications—pressure, temperature, liquid level. *Mercoid Corp.*

1224. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1225. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

1226. Boron Additive
6-page article on use of grainal as boron additive alloy and properties of grainal steels. *Vanadium Corp.*

1227. Brazing
How high-temperature honeycomb structures are brazed printed in Low-Temperature Brazing News, No. 77. *Handy & Harman*

1228. Brazing
52-page publication GEA-3193C on how and where to use electric furnace brazing. Limiting creep of brazing metal, selecting the brazing metal, strength of furnace-brazed parts, how to braze cast iron, causes of distortion. *General Electric*

1229. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

1230. Castings
12-page bulletin on ArmaSteel castings. Properties, applications, machinability and heat treating. *Central Foundry Div.*

1231. Castings
Die and permanent mold castings in aluminum and zinc discussed in new brochure, "Improve Your Products! Lower Your Costs!" *Peasley Products, Inc.*

1232. Centrifugal Castings
Folder on advantages of centrifugally cast thermalloy. *Electro-Alloys*

1233. Ceramics
4-page folder lists industrial products and bulletins describing them. *McDanel Refractory Porcelain Co.*

1234. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1235. Chromium Plating
Bulletin CFC-1 on advantages of crack-free chromium plating process. *Metal & Thermit*

1236. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

1237. Chromizing
4-page folder describes how to make iron powder components resistant to rust and wear. *Chromalloy*

1238. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

1239. Coating
New folder on zinc phosphating compound designed to give a heavy coating in tank applications. *Oakite*

1240. Coatings
Bulletin gives uses of various conversion coatings for zinc and cadmium. *Chemical Corp.*

1206. Magnesium Alloys

Magnesium-thorium alloys HK31A, HM21A and HM31XA for elevated temperature use are described in this 28-page booklet. Design characteristics of this group of alloys, including buckling resistance, stiffness characteristics and thermal barrier characteristics, are discussed as well as such shop

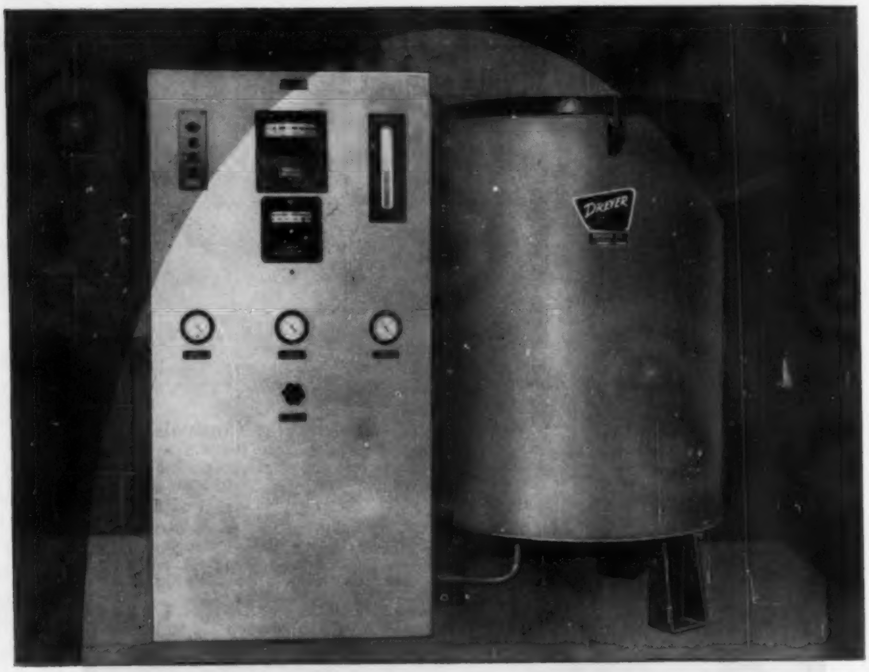
characteristics as machining, forming, joining, assembly and finishing. Property data includes a comparison of the structure temperatures of the magnesium-thorium alloys with those of various other metals for different flight times, mach numbers and altitudes. *Dow Chemical Co.*

1241. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

1242. Cold Forming
4-page folder on die-form process for cold reduction of steel bars into multi-diameter shaft blanks for finish turning or grinding. *Republic Steel*

1243. Cold Rolled Steels
New 48-page Handbook MS-158 on roller die, cold forming metal shapes. Material selection, specifications. *Van Huffel Tube Corp.*

1244. Controller
New 12-page Bulletin 5A-13A on pneu-


DREVER

matic indicating controller for process variables. *Foxboro*

1245. Controls
Data Sheets ND46-33(107), NU9(3) and Folder ND4(7a) on control system which will continuously regulate power input to a variety of electric furnaces. *Leeds & Northrup*

1246. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

1247. Corrosion Resistant Alloy
20-page booklet on nickel, chromium, molybdenum, iron alloy gives chemical composition, corrosion data, properties and welding characteristics. *Haynes Stellite*

1248. Creep Testers
Pocket-size creep load calculator that determines the pounds of weight needed on weight pan when testing specimens in creep testers. *Arcweld Mfg. Co.*

1249. Cutting Machine
New 16-page Catalog 804B on flame cutting machine. Design and performance features. Gas distribution system, accessories. *Air Reduction Co.*

1250. Degreasing
New Bulletin No. 70 on degreasing with trichlorethylene. Advantages and disadvantages. *Hooker Electrochemical*

1251. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

1252. Dryer
New Bulletin 130 describes Aero aftercooler for removing moisture from compressed air and gas. Application of equipment. *Niagara Blower Co.*

1253. Ductile Iron
New 12-page Bulletin MPC provides data on application of ductile iron for machine parts. Material specifications. *Cooper-Bessemer*

1254. Ductile Iron
New bulletin on magnesium-ferrosilicon for ductile iron. Analysis of magnesium ferroalloys. Role of magnesium in ductile iron. *Electro Metallurgical*

1255. Electric Furnace
4-page bulletin 515 on high-temperature electric furnace. Design and construction. *Burrell Corp.*

1256. Electric Furnace
Bulletin 5610 on rocking electric furnace with motor-driven electrodes. Ratings, special features and characteristics. *Detroit Electric Furnace*

1257. Electric Furnaces
Data sheet describes and gives specifications of standard nonmetallic resistor furnaces. *Harrop Electric Furnace Div.*

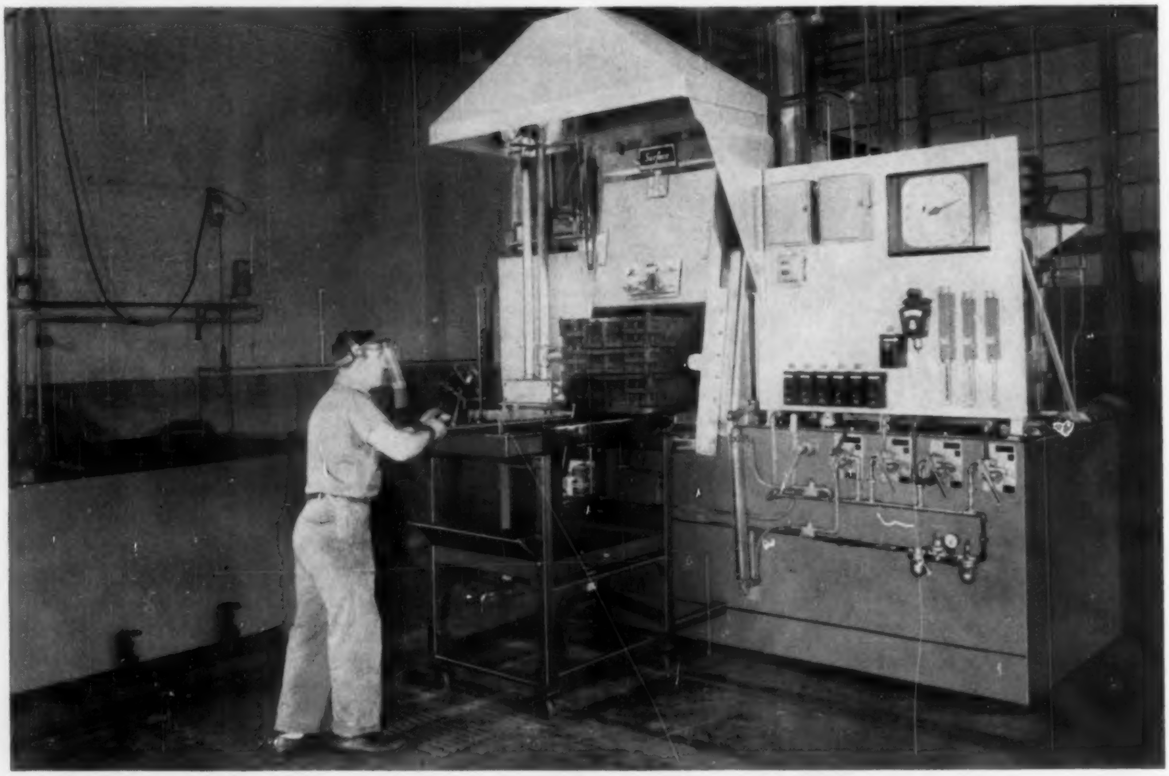
1258. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1259. Electric Furnaces
Bulletin on furnaces for all types of heat treating and hardening, both standard and custom designed. *Pacific Scientific*

1260. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1261. Electric Heating
4-page bulletin on electric heating elements for pipe, tube and tank heating. Sizes, temperature control, element life and installation discussed. *Cooley Electric*

Allcase® furnace clips cost ½ on manicuring implements



One man and one furnace now match the former production of two men and two furnaces in this plant. Added to this gain are two others: greater versatility in processing, and finished work of uniformly high quality. The latter is especially important to this manufacturer of manicuring implements, because he offers a lifetime guarantee on many of his products.

The "hero" of this story is the Surface Allcase® furnace, which is used for hardening, carbonitriding, carburizing, and annealing. Controlled atmosphere is supplied by a Surface MRX® gas generator. Work handling and atmosphere control can be completely automatic, if you wish. Why don't you find out about this profitable furnace now?

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1262. Electrocoated Wire
8-page bulletin on new wire materials—Nickelply and Brassply, electrocoated steel wire. How it may be formed, bent and twisted without breaking the coating. *National Standard*

1263. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

1264. Fabrication
Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

1265. Finishing
New 44-page Catalog 1169-B on 15 models of finishing machines. Automatic size control, floor plans for all models, applications. *Gisholt Machine Co.*

1266. Finishing
New bulletin describes final finishes for new forging dies. Cleaning and refinishing used forging dies. *Vapor Blast Mfg.*

1267. Finishing Systems
New 8-page Catalog No. 600 on cleaning, painting and baking equipment. 17 isometric drawings. *Schmieg Industries*

1268. Flame Hardening
20-page catalog on flamatic hardening machines and allied equipment. *Cincinnati Milling Machine Co.*

1269. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1270. Formed Plate
Bulletin on stainless steel elliptical flanged and dished heads. 171 available dies listed. *G. O. Carlson*

1271. Freezer
Data on chest for use down to −95° F. for production use and testing. *Revco*

1272. Furnace Supplies
8-page catalog on accessories to melting furnaces including linings, silicon-carbide base blocks, burners, blowers, pots. *Lindberg Engineering*

1273. Furnaces
Bulletin 209 on luminous wall firing system. Design of furnace, heating and cooling rates. Advantages of instantaneous heating. *A. F. Holden*

1274. Furnaces
Metal Melting Newsletter on push-out furnace, a removable crucible furnace. *Inductotherm Corp.*

1275. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1276. Furnaces
Monthly bulletin on used equipment. *Metal Treating Equipment Exchange*

1277. Furnaces
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1278. Galvanized Steel
New 34-page booklet on zinc-iron alloys. Fabrication, how to weld and solder, typical uses. *Armco*

1279. Gas Analyzers
20-page booklet on continuous analyzers for combustible gases. Alarm systems. *Mine Safety Appliances Co.*

1280. Gas Unit
Bulletin HD-257 on gas preparation unit gives gas composition and chemical reactions, advantages. *Hevi Duty*

1281. Gold Plating
8-page paper gives bath composition, equipment and operating conditions, and metallurgical characteristics of 24K gold plate on various base metals. *Sel-Rex*

1282. Gold Plating
Physical, thermal, chemical, electrical, diffusion and optical properties of electroplated gold. Uses. *Technic*

1283. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1284. Hardness Conversion Tables
Celluloid card, 2¾ x 4¾ in., gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. *International Nickel*

1285. Hardness Conversions
Desk-size chart of conversions for Rockwell tests and other hardness scales. *Torsion Balance Co.*

1286. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1287. Hardness Tester
Data on portable tester with five most widely used hardness scales. *Co. for Technical Progress*

1288. Hardness Testers
New 24-page Catalog No. DH-327 on accessory and special testing. *Wilson Mechanical Instrument Div.*

1289. Heat Exchangers
Bulletin 105 on heat exchangers, their pressure ratings and heat transfer ratings. *Thermal Research & Engineering Corp.*

1290. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion Div.*

1291. Heat Treating
Heat Treat Review, Vol. 8, No. 3, contains a discussion on "automation" in your heat treating department. *Surface Combustion*

1292. Heat Treating Belts
New 12-page catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

1293. Heat Treating Equipment
New 24-page Catalog 54 on light-weight processing and heat treating equipment. *Pressed Steel Co.*

1294. Heat Treating Fixtures
32-page catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat-treating equipment, pickling equipment. *Rolock*

1295. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1296. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

1297. Heat Treating Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1298. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

1299. Heat Treating Supplies
Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

1300. Heat Treatment
Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

1301. Heating Element
New 12-page catalog on 35-20 nickel-chromium-iron heating element. Temperature-resistance curve, physical property tables and factors to consider in designing furnace elements. *Hoskins Mfg. Co.*

1302. Heating Elements
Bulletin on cast heating element used in electric furnace. Various methods of mounting. *Electric Furnace*

1303. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1304. High-Strength Steel
New 24-page bulletin on steel bars made by elevated temperature drawing. Strength without heat treatment, machining data, fatigue resistance, wearability. *LaSalle Steel*

1305. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U. S. Steel*

1306. High-Strength Steels
New folder on manganese-copper steels. Properties, fabricating practice. *Republic Steel*

1307. High-Temperature Castings
16-page manual on heat and corrosion resisting castings. Principles of alloy composition, their properties and limitations, stabilizing influences and heat treatment. *Michigan Standard Alloy*

1308. Hydraulic Tables
New 40-page Bulletin No. 3300 on presses and applications. 28 pages of tables on decimal equivalents, hydraulic ram capacities, wire and sheet metal gages, strength of material, etc. *Hamilton Div., B-L-H*

1309. Induction Heating
36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

1310. Induction Heating
New 12-page booklet on the A-B-C's of induction heating for extrusion, forging, brazing, heat treating and metal joining. *Magnethermic*

1311. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

1312. Inspection
16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument Div.*

1313. Laboratory Equipment
16-page Laboratory Spotlight lists optical equipment and instruments for metallurgical laboratory. Cut-off machines, polishing tables, etc. *Harshaw Scientific*

1314. Laboratory Equipment
Bulletin on high-purity graphite powder, funnels, crucibles, boats. *United Carbon Products*

1315. Laboratory Furnace
Data sheet on high-temperature laboratory furnace for operation at 4600° F for crucible melting. *Zirconium Corp. of America*

1316. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U. S. Steel*

1317. Lubricant
Bulletin 426 on use of colloidal graphite for forging, wire drawing, piercing, drawing, extrusion and other metalworking operations. *Acheson Colloids*

1318. Lubricant
New 24-page Bulletin No. 115 on preparation of metal surfaces for proper application of lubricant by either spraying or dipping. *Alpha Molykote*

1319. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

1320. Manganese Steel
New booklet on rolled and forged nonmagnetic high-manganese steel. 5 pages of applications. *Manganese Steel Forge*

1321. Marking Machines
Data on various types of marking machines from bench mounted machines for light duty marking to machines capable of marking at up to 6 tons table pressure. *Jas. H. Matthews & Co.*

1322. Melting Furnace
6-page folder R-53 on 60-cycle combined melting and holding furnace for continuous casting of aluminum. *Ajax Engineering*

1323. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

1324. Metal Sorting
Data on nondestructive sorting tool for raw, semi-finished or finished parts. *J. W. Dice*

1325. Metallograph
8-page catalog E-240 on research metallographic equipment discusses microscope unit, illuminator, optical equipment, camera, focusing arrangements. *Bausch & Lomb*

1326. Microscope
New Technical Bulletin HHS-2 on vacuum heating stage which permits specimens to be examined at temperatures ranging from room temperature to 2000° F. Application, specifications. *Unitron Instrument Div.*

1327. Molybdenum Borides
6-page bulletin on applications, chemical, physical and mechanical properties of refractory molybdenum borides. Preparation of compounds. *Climax Molybdenum Div.*

1328. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1329. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1330. Ovens
New Bulletin 4-257 on gas, oil and electric ovens. Load carrying door, electric drawer and walk-in type ovens. *Grieve-Hendry*

1331. Oil Quenching
Bulletin No. 11 on quenching oil also discusses advantages of quench agitation. *Sun Oil Co.*

1332. Permanent Magnets
New 12-page Catalog No. PR-19 on permanent magnets, magnetizers, and de-
(Continued on page 48-A.)

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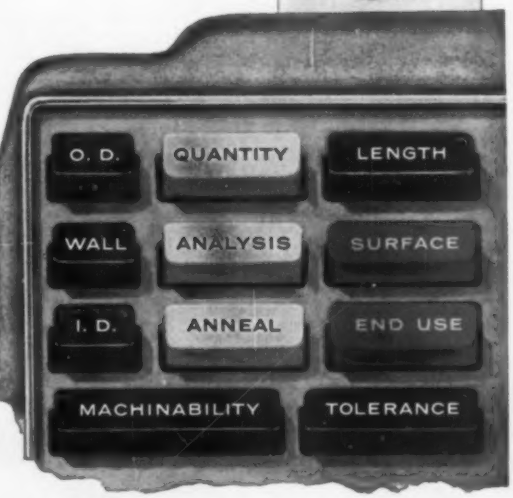

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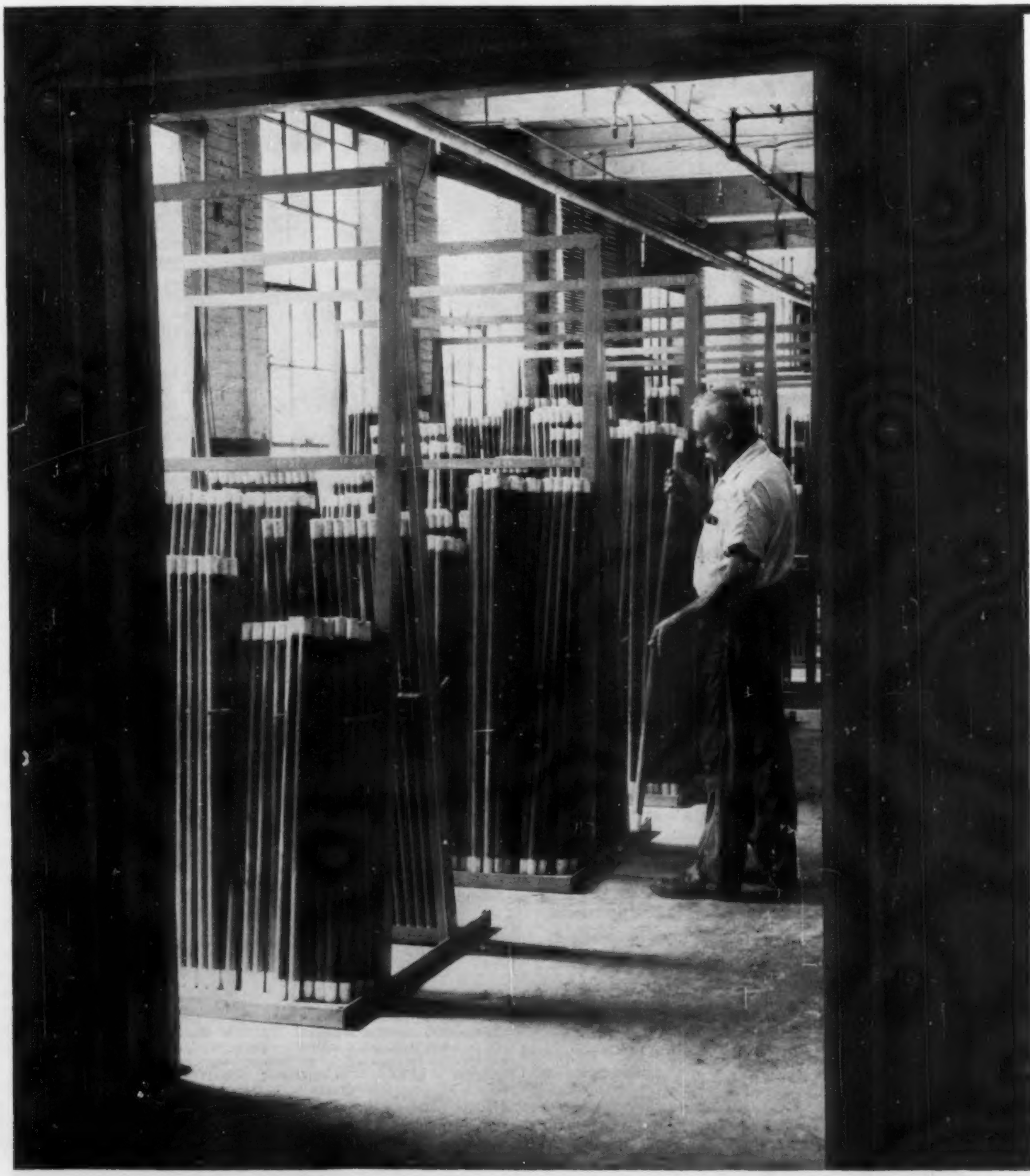

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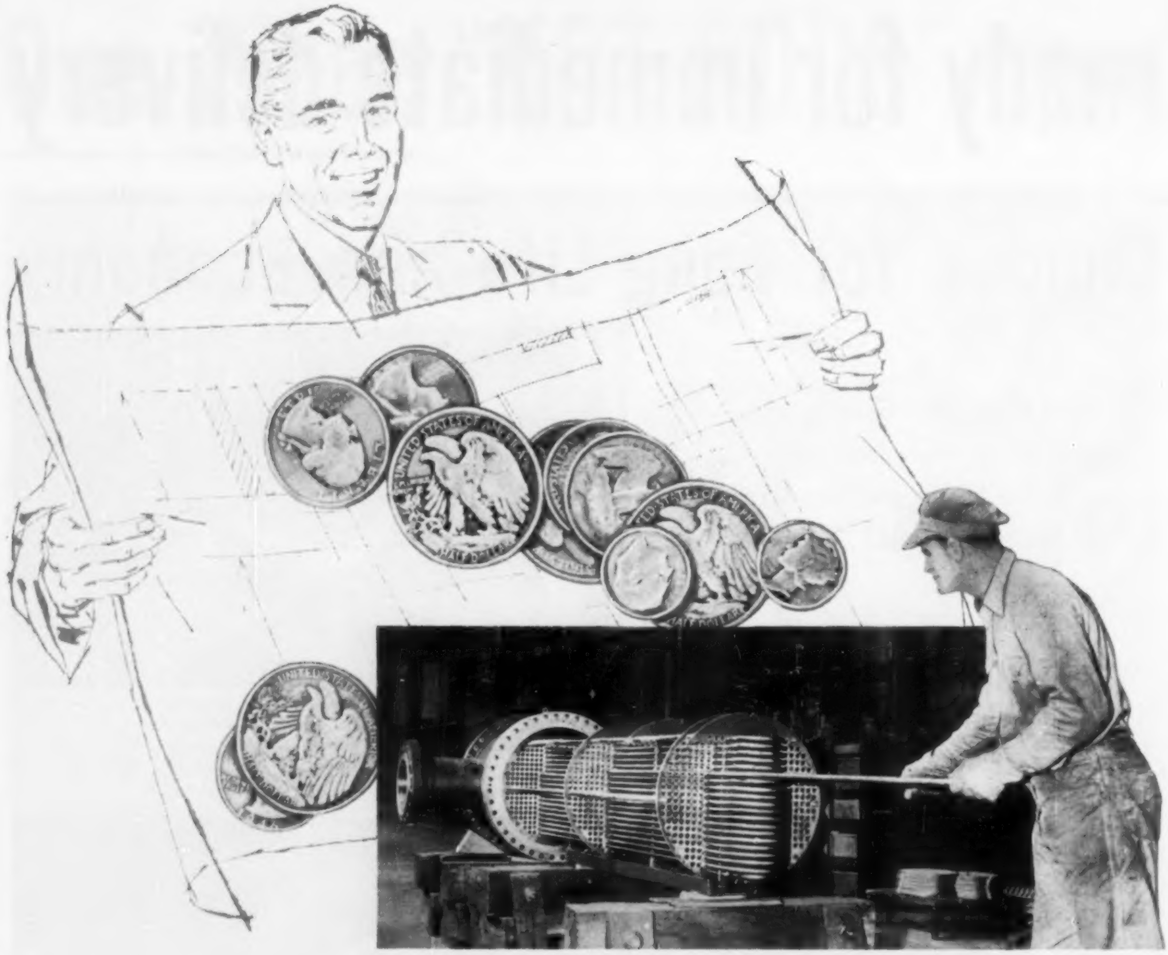

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(Continued from page 43)
magnetizers. Over 100 magnets available. *Indiana Steel Products*

1333. Phosphating
Folder includes general discussion of phosphating, how it works and use of coatings as bonds for paint or other organic finishes. Phosphating reference chart. *Turco Products*

1334. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1335. Pipe
4-page bulletin on Yoloy continuous weld pipe. Chemistry, properties, corrosion resistance. *Youngstown Sheet & Tube*

1336. Plating
8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers. *R. O. Hull*

1337. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

1338. Potentiometers
4-page Bulletin 1271 on small self-balancing electronic potentiometers and bridges. *Bristol Co.*

1339. Powder Metallurgy
Technical literature on high-density sintered metal parts. *Supermet Div., Globe Industries*

1340. Powdered Iron
Properties of Plast/Iron with and without copper. *Plastic Metals Div.*

1341. Press
New Bulletin 380 on powdered metal press. Description, operation, specification. *Watson-Stillman Press Div.*

1342. Press
New Bulletin No. 1200 on 50-ton multiple-motion powder metal press. Operating characteristics, physical specifications. *F. J. Stokes*

1343. Pressure Tubing
New 16-page Bulletin No. TB-417 on pressure tubing and pipe for the process industries. Analysis, physical, mechanical and creep strength properties. *Tubular Products Div., B & W*

1344. Quench Agitation
32-page booklet on 1 to 500 hp. mixers, construction, operation, applications. *Mixing Equipment Co.*

1345. Quenching
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

1346. Radiation Equipment
Radiation Digest, March-April 1957, contains cost sheet comparing costs of inspection by electron or gamma-ray irradiation equipment. *General Electric, X-Ray Dept.*

1347. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

1348. Radiography
28-page booklet on products for industrial radiography gives exposure and processing data for various film used. *DuPont, X-Ray Div.*

1349. Rare Earth Metals
54 references to applications of rare earth metals in aluminum, cobalt, magnesium, nickel and other nonferrous alloys. *New Process Metals, Inc.*

1350. Refractories
12-page catalog shows properties of impervious recrystallized alumina and impervious mullite. Shapes into which each is fabricated. *Morganite, Inc.*

1351. Refractories
24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

1352. Rolling Mills
New Catalog FRM-58 on mills for laboratory and development, wire flattening. Accessories. *Fenn Mfg.*

1353. Rust Prevention
Nine bulletins in one folder on rust prevention. Theory of corrosion. Applications. *Production Specialties*

1354. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1355. Salt Baths
New 76-page Catalog 117 on salt bath equipment and procedures. Includes new ceramic tile pot furnaces with removable submerged electrodes. Technical data, applications. *Ajax Electric*

1356. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1357. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1358. Spectrographs
24-page brochure on prism and grating spectrographs and related accessories. Design, application and characteristics of each instrument. Performance ranges. *Jarrell-Ash Co.*

1359. Spectrometer
8-page Bulletin 44 on direct reading spectrometers. Operation and construction. *Baird Atomic*

1360. Spring Steels
New 8-page bulletin on tempered spring steels. Six physical property charts. *Wallace Barnes Steel Div.*

1361. Springs
New 16-page Catalog No. 9 on micro processed springs of beryllium copper. Design recommendations, specifications. *Instrument Specialties Co., Inc.*

1362. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

1363. Stainless Steel
20-page catalog on corrosion resistance, applications and working characteristics of 20% chromium—29% nickel stainless steels, with and without columbium. *Carpenter Steel*

1364. Stainless Steel
16-page booklet on Type 430 stainless gives physical properties and analysis, corrosion resistance, fabrication, application and care. *Washington Steel*

1365. Stainless Strip
32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties, corrosion resistance. *Superior Steel*

1366. Steel Tubing
New catalog on seamless and electric-resistance welded steel tubing. Sizes, shapes, compositions. *Ohio Seamless Tube*

1367. Steels
New reference data sheet on tungsten-molybdenum high speed steel. Heat treatment, compositions, applications. *Vanadium Alloys Steel Co.*

1368. Sub-Zero Treatment
12-page booklet on industrial chilling

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Bulletin No. 4 on universal tester. Capacities, accessories. *W. C. Dillon*

1370. Testing Machine
New Bulletin No. 41 on LC type testing machine. Dual capacity ranges of 10,000 and 1,000 lb. Can be used for compression, tensile and transverse tests. *Tinius Olsen*

1371. Testing Machines
Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

1372. Thermocouple Assemblies
New Bulletin E on thermocouples, thermowells, connection heads and fittings. Types and alloys in which they are available. *Thermo Electric*

1373. Thermocouple Data
New bulletin F-5228-3 on construction and application of thermocouples and radiation detectors to industrial control. How to check, make, select and size thermocouples. *Wheelco*

1374. Thermocouples
32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument*

1375. Titanium
New 8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with zirconium, tantalum and stainless in various mediums. *Mallory Sharon*

1376. Titanium Powders
Data on high purity and commercial titanium powders. *Hawkridge Metals*

1377. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Uses. *Bethlehem*

1378. Tool Steel
4-page bulletin on Ry-alloy, oil-hardening tool steel. Applications, advantages, heat treatment and forging practice. *Ryerson*

1379. Tool Steels
13-page directory of tool and die steels gives SAE designations with compositions, properties, forging and heat treating data, trade names. *Cannon-Muskegon Corp.*

1380. Tool Steels
New 44-page Stock List No. 12 is indexed and includes sizes, weights, and analyses. Decimal conversion and hardness conversion tables. *Uddeholm*

1381. Torsion Testers
New 8-page Bulletin RT-10-54 gives details of construction, pendulum-type testers, torsion testers for wire. *Riehle*

1382. Tubing
New 16-page bulletin on how formed tubes are made. Bending and welding operations. *Formed Tubes, Inc.*

1383. Tubing
New 6-page Data Memorandum No. 20 on tubing for atomic power. Uses, characteristics and size limits, applications. *Superior Tube Co.*

1384. Tubing
New 6-page folder on tubing applications in nuclear power plants. *Wolverine Tube Div.*

1385. Tubing
New 64-page handbook on use of tube mills in manufacture of pipe and tube. Step-by-step description of the electric-weld process. *Yoder*

1386. Tungsten
20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

1387. Tungsten Alloy
New bulletin on properties and uses of 90% tungsten alloy, balance nickel and copper. *Firth Sterling, Inc.*

1388. Tungsten Carbide
Technical data and advantages of tungsten carbide with platinum binder for wear resistant and corrosion resistant applications. *Kennametal, Inc.*

1389. Ultrasonic Inspection
Ultrasonic Inspection Newsletter, No. 2, contains article on immersion inspection of wing spars for jet fighters. *Sperry Products*

1390. Ultrasonics
Data sheet on gages for thickness measurement, coating measurement, inspection. *Branson Instruments*

1391. Vacuum Coating
Bulletin on principles, production steps, applications, equipment. *NRC Equipment*

1392. Vacuum Furnace
New Data Sheet 660 on a vacuum melting furnace with melt capacity of 50 lbs. *F. J. Stokes*

1393. Vacuum Melting
New bulletin on vacuum melting furnaces which can be used in production or laboratory. *Zak Machine Works*

1394. Vacuum Metallurgy
Information memo tells of materials handling in vacuum metallurgy. *Consolidated Electrodynamics, Rochester Div.*

1395. Vacuum Metals
21-page report on vacuum melted metals discusses equipment, properties of metals and their applications. *Ajax Electrothermic Corp.*

1396. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

1397. Welding Electrodes
New 88-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

1398. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1399. Welding Stainless
New 12-page booklet—a guide to better welding of stainess steels. In question and answer form. *Arcos*

1400. Woven Wire
New 22-page catalog on woven wire gripper slings. Advantages, typical uses, technical data. *Cambridge Wire Cloth*

1401. Wrought Iron
New 16-page booklet, "The ABC's of Wrought Iron." What it is, how it is made, fabrication, corrosion resistance, applications. *A. M. Byers Co.*

1402. X-Ray Diffraction
New 14-page booklet "Questions and Answers" on X-ray diffraction, diffractometry and spectrography. *Philips Electronics, Inc.*

1403. X-Ray Equipment
4-page folder on X-ray viewer. Advantages and application. *Philco*

1404. X-Ray Supplies
Bulletin on X-ray films and chemicals for radiography. *Ansco*

1405. Zinc Coating
New 8-page booklet on zinc-coated steel sheets. Fabrication, uses. Advantages in heating, ventilating and air conditioning. *Weirton Steel*

1406. Zirconium
8-page brochure on zirconium's corrosion resistant properties. Applications based on this property. *Carborundum Metals Co.*

June, 1958

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1197	1218	1239	1260	1281	1302	1323	1344	1365	1386	
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1201	1222	1243	1264	1285	1306	1327	1348	1369	1390	
1202	1223	1244	1265	1286	1307	1328	1349	1370	1391	
1203	1224	1245	1266	1287	1308	1329	1350	1371	1392	
1204	1225	1246	1267	1288	1309	1330	1351	1372	1393	
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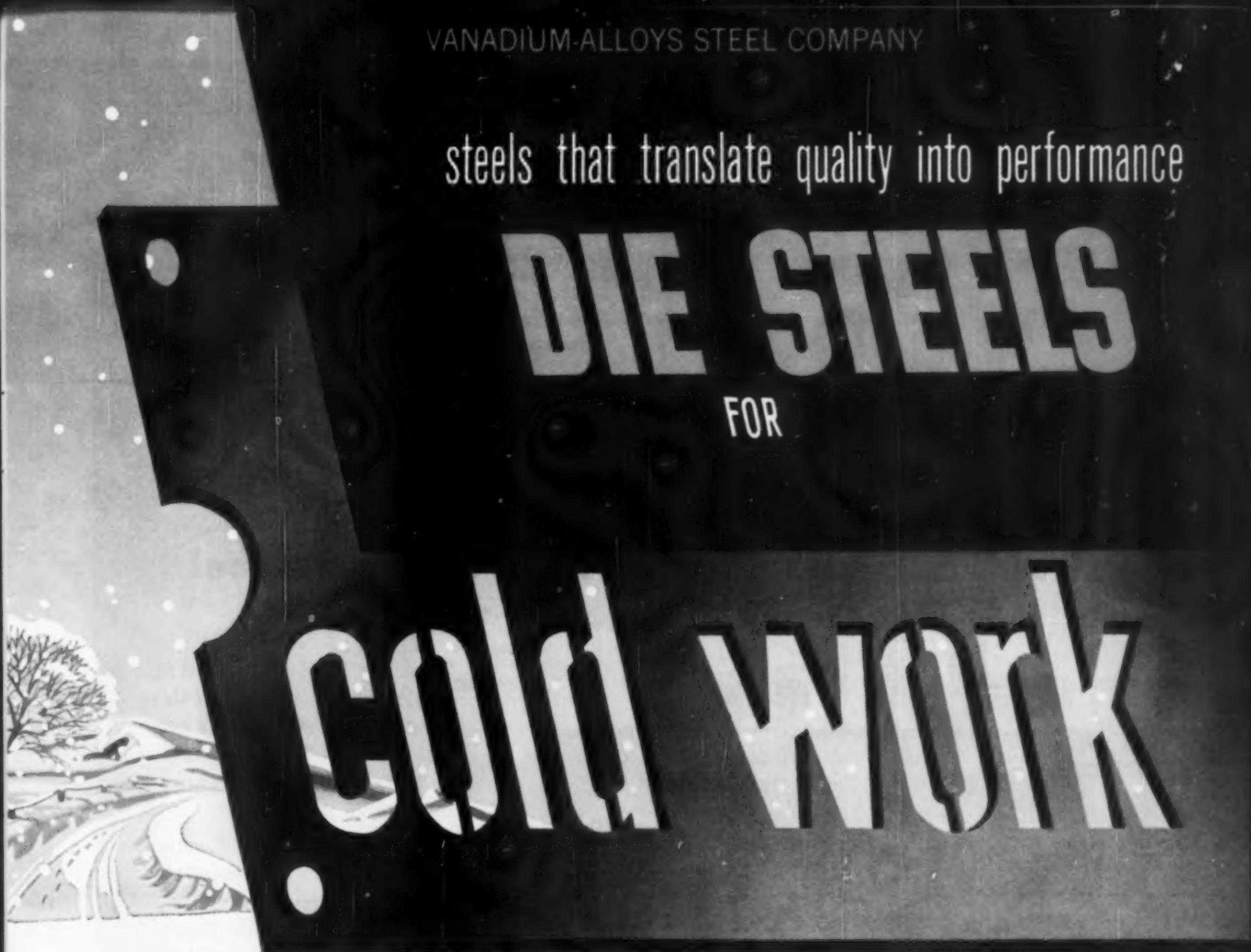

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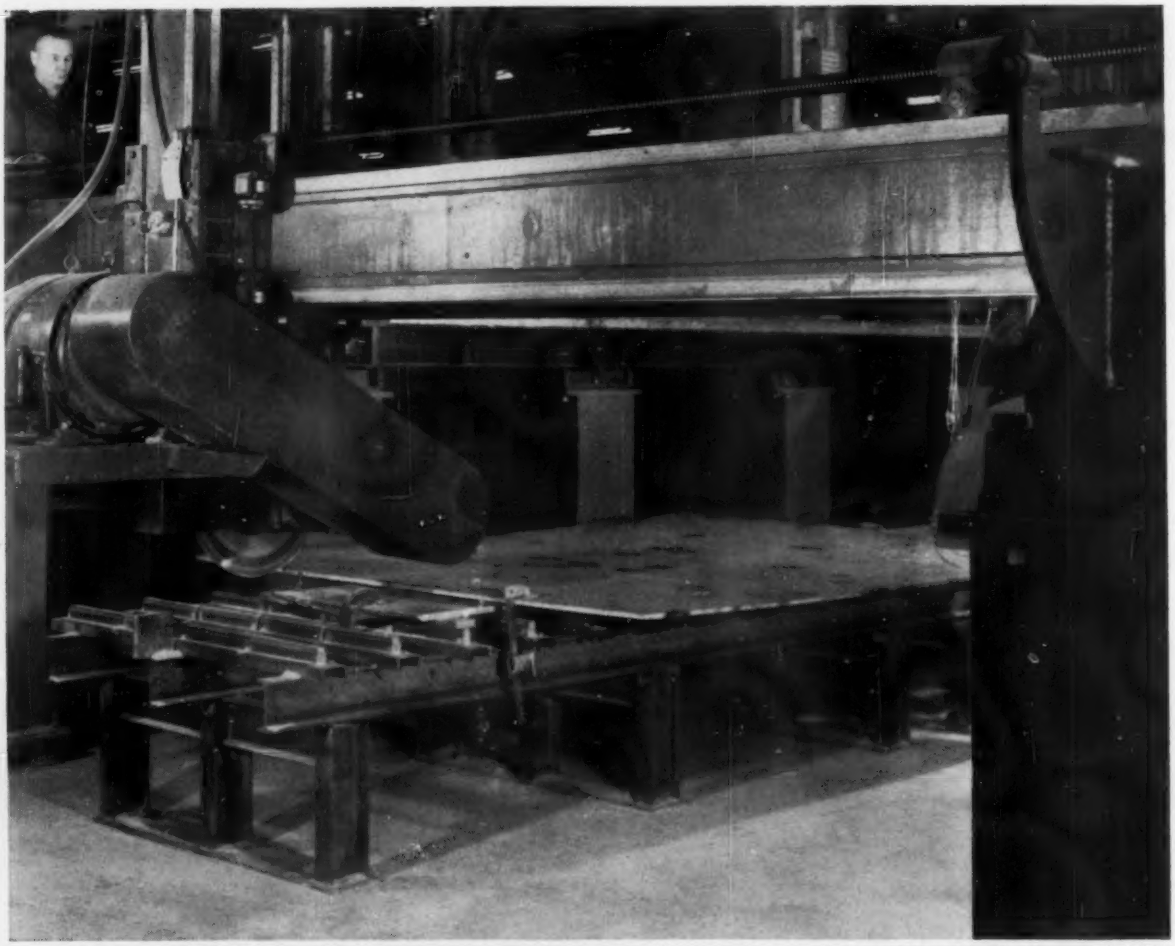

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In Memoriam

William Hunt Eisenman

1886-1958

It is with heavy heart that these lines are written, recording the sudden death on May 30 of William Eisenman, the life-long Secretary of the American Society for Metals. It is even with a sense of unbelief – unbelief that his dynamic personality will no longer be with us. But when this shock subsides, we will know that he in fact remains with us, for the American Society for Metals will continue to grow along the lines he mapped. His whole life was the American Society for Metals. He has achieved immortality in a very real way; he started 40 years ago with what was little more than an idea; this idea became an ideal to work toward; this ideal will continue to draw the best efforts of many men and women as long as we can foresee. His memorial is a living thing, a growing thing.

The life story of William Hunt Eisenman has been told elsewhere, and will be told again. He was blessed by a rugged constitution which carried him through a working life which would have exhausted two strong men. Very, very seldom, if ever, did he let his private fatigues show in his personal relationships. He always had a hearty, welcoming smile. Best of all, he always meant it; there was no sham about Bill.

You could not imagine a closer identification between man and work than existed between Bill and the A.S.M. There is a story that when he heard of the first resignation from the American Steel Treaters Society (as it was called in 1917 in Chicago), he got on a trolley car and hunted up the recalcitrant to find out what was wrong with the Society. It is a story that must be true, for it is completely in character. Else why should he spend half his time, year after year, visiting the chapters from Boston to San Diego, and from Vancouver to Jacksonville, spending the days with executive committees and the evenings at the chapter meetings? Everyone who has taken any part in Society affairs knows of his intense personal interest in the local problems and how the national office might help.

It would be superfluous to tell of the many things the American Society for Metals has done under his direction, of the plans already laid and well under way for the tremendous role which the Society must play in America's future. He gave of himself unstintingly that these ideals might be achieved. May all of us derive inspiration from the life of a real man, a good American and a staunch Christian.

Rest in Peace

Critical Points

Spark Plugs and Die Castings

THE CONFUSION which exists between mass production and "automation" (God save the word) seems to have spread up to President Eisenhower. In a recent televised conference he compared the vanished artisan, who took pride in making a better wheelbarrow than ever before, with the machine-tender of today, who continually feeds pieces of metal into a shear. But machine-tending is not "automation", as he called it. Real automatic production would start with a coil of wide strip at one end of a machine line and complete wheelbarrows would roll out the other.

This difference between mass production and automatic production is quite evident to a visitor at the Flint, Mich., plant of AC Spark Plug Div. of General Motors. Arthur Tinetti, plant metallurgist, was showing me a battery of die-casting machines. Now die casting is certainly a method for mass production, and there were plenty of the machines operating at a good clip, each with its own machine tender. In the department was a pair of really automatic ones, operating at a speed limited principally by the heat-transfer process, for knockout and lubrication were part of the machine cycle. Simple mechanisms replaced the operator.

That's more like automation. Hot metal comes in as needed from a melting pot; finished castings go away on a belt conveyer. It wouldn't be too difficult to transfer the hot castings to a trimmer, and deliver castings on one conveyer, flash and sprue scrap on another.

There are many such places in the plant at Flint where operations – especially assembly operations – are mechanized. An automatic line of this sort can obviously be economic only when the output runs into almost astronomical numbers. Another factor which is not so obvious is that the inspection and tolerances on each individual part must be closer. Assembly by hand is in itself a rather high quality of 100% inspection; the skilled assembly girl instinctively recognizes infinitesimal differences and discards the suspicious pieces. Not so the machine; the only thing it can do is stop if a badly misshapen part gets in the way.

(**Metallurgical Note:** In the magnesium department, the cold chamber process is preferred. Pistons and other submerged parts on the hot machines erode rapidly in the molten alloy and lose their fit – even when surfaced with Carboloy or other cermet.)

Karl Schwartzwalder, director of research, showed me the ceramic end of spark plug manufacture. The insulators look like glazed china sleeves. Alumina comes in by the car load; it is of a purer grade than ordinarily used for reduction to aluminum because it is refined of last traces of sodium. Particle size is carefully controlled by regrinding in ball mills (sintered alumina balls and liners, to prevent contamination). Particles are coated with organic binders by mixing with a water solution into a creamy "slip", and then evaporating the water. Pressing the dry powder into the sleeve-like shapes is done on automatic presses; accuracy is essential for there is a 35% shrinkage on firing – in fact, exacting care with infinite detail is the result of 50 years of study.

Future Scientists

While at Flint, I acted as one of the team of judges of the annual Flint Science Fair. Grammar school pupils, junior high schoolers, and senior high schoolers of the city and county submitted nearly a thousand exhibits, each one a student project intended to show some scientific principle, laboratory procedure or industrial operation. Just to exhibit them required one auditorium and one gymnasium. Just to mount them required a hundred men, working

until midnight. Just to judge them required all day for another hundred.

The work of the high schoolers was enough to open your eyes. One girl tried to find out why her bobby socks stretched out of shape so rapidly; suspecting it had to do with laundering she devised and carried through a series of controlled experiments which would have done credit to the Bendix laboratory staff. One boy had made a stroboscope which worked; another had a model which illustrated interference of light waves by setting up various waves in a shallow water container; a third had a tape-recorded lecture on the thermonuclear reaction nicely synchronized with illuminated models.

Russians, look out; we've got a new crop of scientists and engineers growing up!

What Price Titanium?

THE EDITOR was welcomed at Pratt & Whitney Aircraft in East Hartford and in a day-long inspection of the entire factory got some idea of the unusual operations necessary for handling titanium. For example, welding is done in what the atomic scientists call "glove boxes" or rather "glove bags" of transparent plastic; the work and tools are manipulated by the workman's hands inserted into built-in gloves. This bag, originally collapsed, is flushed and filled with argon to prevent contaminating the hot metal with atmospheric oxygen or nitrogen. Unfortunately, too many of the joints were below standard, even though procedures seemed to be correct. Someone mentioned the possibility of air infiltration, so now an incandescent lamp (without the usual protective glass bulb) lights up inside the bag. If the filament burns out, welding stops, for it is a sign there's too much oxygen there.

Pratt & Whitney Aircraft uses more than half the entire American production of titanium alloys in the compressor end of two of its advanced jet engines. About 3200 lb. of mill shapes work down into 675 lb. of parts for the J-75 engine for supersonic fighters, and 3000 lb. of mill shapes make 570 lb. of parts for the J-57 (Series C), eight of which power each intercontinental B-52 bomber. While this shrinkage (5 into 1) seems exceedingly large, the corresponding parts of the mostly-steel J-57 version weigh 870 lb. and are derived from 4380 lb. of mill shapes. The ratio of shrinkage, 5 to 1, is the same, but unfortunately titanium scrap at present is comparatively worthless.

One can readily see that the "stretch-out" in the B-52 production program in mid-1957 really slowed down the titanium industry, plus the decision to use an all-steel version of the J-57 engine on the four-engine tankers being built. While it is worth almost anything to save weight on a supersonic bomber or fighter, else the craft might fail in its mission, a work horse of shorter range is another thing.

The way the cost of highly elaborated metal parts pyramids is uncanny. Titanium is no exception to steel or aluminum in structure or to nonferrous metals in gadgetry – only you start off with a higher base price of the raw material. For example, much has been made of the fact that while Grade A sponge was quoted at $5 per lb. in 1951, it is now $2.05, but hot rolled bars of commercial titanium still cost $6 and alloy forgings $12 per lb. – in fact, alloy sheet of aircraft quality may cost as much as $15.

Since there is a 5 to 1 shrinkage on the average from the mill to the engine, the titanium alloy parts therefore cost from $50 to $75 per lb. for raw material alone, depending on whether they are made from bar or sheet. Even when you add the shop costs of fabrication, sometimes using such specialized operations as noted above for welding, it is rather surprising to read in a 1957 staff study to the Materials Advisory Board that the steel version of the J-57, weighing 300 lb. more than the one using titanium, costs about $100,000 less. It apparently was costing about $300 to save a pound of weight in a powerful aircraft engine by using titanium.

Even so, the people at Pratt & Whitney do not seem to be at all discouraged. They know that their J-57 engine leads the field in thrust-weight characteristics. The present low demand for mill products and high production capacity is certain to bring down titanium prices. The chances are good that the production of the intercontinental B-52 bomber will be stepped up in the near future. There will be at least one more "generation" of long-range bombers and Mach-3 fighters before missiles take over American defenses in the air (if they ever do), and these aircraft will have to have something at least as good as the J-57 engine with titanium (and probably use a titanium skin on the front half of fuselage as well). An additional fact: each of the new jet planes for civilian passenger service to be delivered by four American builders in 1959 and 1960 will use from 1000 to 1500 lb. of titanium in the hot spots of the structure.

Chins up! E. E. T.

Heat Treating of Roller Bearings Is Geared to Automatic Production

*By LEO H. EVERITT and O. E. CULLEN**

Timken has unveiled its Bucyrus, Ohio, plant which has an annual capacity of 27,000,000 roller bearings. (The Russians recently boasted of a plant producing 1,500,000 roller bearings a year.) Production is completely automatic from machining through heat treating to packaging. Much of the success is credited to the push-button heat treat operation of five lines, using 22 furnaces for carburizing, hardening and tempering the bearing components. Here are some good ideas for other manufacturers who need a heat treat operation for a straight-line method of mass production. (J26, J28, J29, T7d, 18-74, 1-52)

A PLANT which could make most of the roller bearings for the entire automotive industry operates without human hands touching the product in any of the operations.

The Bucyrus, Ohio, plant of Timken Roller Bearing Co. produces 33 million cups and 27 million cones per year without approaching its designed capacity. These range from small bearings with 1¾-in. O.D. to larger ones up to 4⅜ in. O.D. From the time the tube stock is placed in the storage rack, which feeds the single-spindle or multiple-spindle automatic machines, to the packaging operation, the bearing components are handled automatically.

Much of the success of the Bucyrus plant is credited to a push-button heat treat operation. It consists of five furnace lines, totaling 22 furnaces, which form the center of a totally automatic production line. All furnaces, generators and conveyers were built and installed by Surface Combustion Corp. working with Timken's engineers.

General Layout for Heat Treating

Two departments, separately operated, perform a complete heat treating operation. One turns out cups – the outside race of the bearing. The other makes cones – the inside race. Because these bearings are made from S.A.E. 4620, a low-carbon, low-alloy, carburizing steel, heat treating is a key factor in production. Timken has integrated a separate heat treating setup into each of its departments which functions much like a huge gear in a production machine. Cups are treated in a four-line setup (Fig. 1), totaling 13 furnaces. Cones are treated in a three-line set-up (Fig. 2) which uses 9 furnaces.

Cup Lines

One line (No. 1 in Fig. 1) treats only the smaller cups which are not subject to distortion, outside of narrow limits. It uses a double-retort carburizing furnace, a single-retort hardening furnace and a single, perforated drum draw furnace of the recirculating air type.

Another line (No. 2 in Fig. 1) treats cups of intermediate sizes, which present distortion and size problems. This requires press quenching. To permit flexibility in size range, the line is set up in single-furnace style, but by using double

*Mr. Everitt is heat treating specialist, Timken Roller Bearing Co., Canton, Ohio, and Mr. Cullen is chief metallurgist, Surface Combustion Corp., Toledo, Ohio.

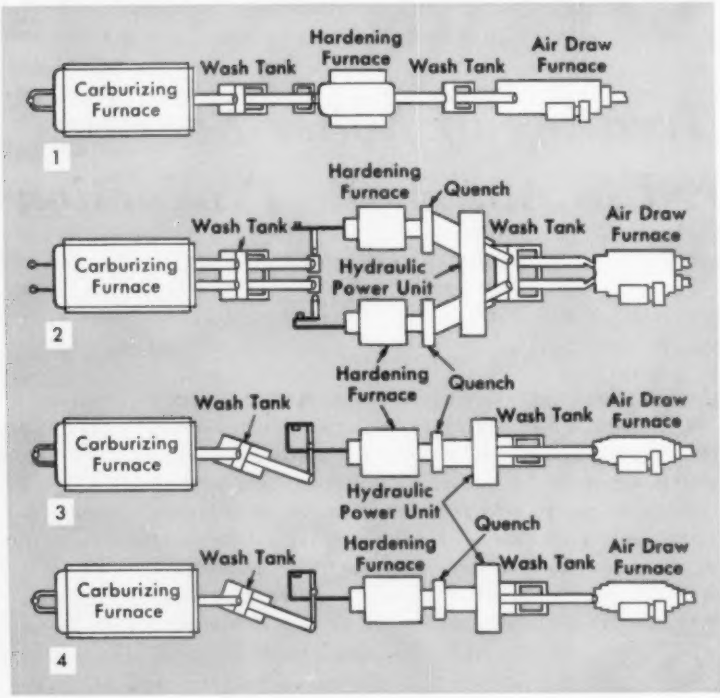


Fig. 1 – Schematic Layout of Automatic Line for Heat Treating Cups (the Outside Race of Bearings) at the Bucyrus, Ohio, Plant of Timken Roller Bearing Co. To permit flexibility in size range, lines are set up in single-furnace style, but by using double retorts in the furnaces, each line acts as two lines. Line 1 treats only smaller size cups which are not subject to distortion. Lines 2, 3, and 4 use an automatic press quench

retorts in the single-furnaces, it acts as two lines. This is accomplished by using one carburizing furnace with two revolving retorts, each being serviced by a separate conveyer.

Two pusher-type hardening furnaces with eight alloy rails do the heating for hardening. Cups are quenched in two separate presses. From the press quench, parts travel separately to a double revolving drum draw furnace.

The remaining two furnace lines (No. 3 and 4 in Fig. 1) are used to quench the larger sizes. Each of these has a double revolving retort carburizing furnace, an eight-rail reheat furnace for hardening, a four-plug quench press and a single revolving drum draw furnace.

Cone Lines

Two of the three cone lines (No. 1 and 2 in Fig. 2) use double revolving retorts in each of the carburizing and reheating furnaces. Again, the dual retorts double the heating chamber capacity. The draw furnaces are equipped with double perforated revolving drums. Dual conveyers permit each line to run two cycles of work simultaneously and thus operate as two separate heat treating lines. The third cone line (No. 3 in Fig. 2) uses single revolving retorts in the carburizing and reheating furnaces and a single revolving drum in the draw furnace. All of the lines use perforated drum conveyers to transfer the parts from one operation to another. Spray washers, also of the perforated drum type, are used to clean the parts after each of the quenching operations.

Gas carburizing is used throughout. Three Surface RX gas generators are used in each of the two departments. Total capacity of each bank of three is 7200 cu.ft. per hr. Gas is piped to each of the carburizing and reheating furnaces from a central point. Atmosphere control gives a product which is completely free of scale.

Metallurgical control is simple and dependable. The operators break a hardened bearing component from each line every half-hour. These are polished, then etched for case depth. An additional check is made to determine carbon level at the depth specified for the component being treated. This is done by the M_s case depth method which is based on quenching the cone or cup from the austenitizing temperature into a salt bath held at a suitable temperature to transform 0.50% carbon and under. The carbon level is determined by the depth of hardness. This method of testing and checking by the operator, right at the furnace location, is fast and assures that all heat treating factors are

of constant quality level. Once a week a sample from each line is sent to Timken's main metallurgical laboratory for a complete chemical, physical and metallographic analysis.

Automatic Controls Are Interlocked

A significant feature of the Bucyrus heat treating lines is their simplicity of control. Most of the automatic controls are of the Micro Switch type; in some instances, photo-electric eyes are used. Each of the units in a line is interlocked by safety switches and synchronized. Additional warning and automatic kickout switches provide safety for individual machines.

Micro Switches and other mechanical control devices have been installed in a way to be free of vibration failure and so they will absorb heavy shock without damage. Failure of this type of equipment is usually due to wear, which occurs slowly and over a long period of time, thus permitting replacement of worn parts or assemblies before complete failure occurs.

Storage Bins Equalize Production

Bearing cups or cones which have been finished-machined are received in storage bins – an integral part of the automatic system. The bins are located at the head of each heat treating line. Similar storage receptacles are located at the discharge end of the heat treating lines. Their purpose is to hold material heat treated over the weekend while the rest of the line is not operating.

The roughing and finishing operations work a five-day week, but it is more economical to operate heat treating facilities continuously. Therefore, roughing and finishing production is geared to produce more than the heat treating furnaces can handle. The machined components gradually build up in the storage bins during the five-day week for heat treating on Saturday and Sunday. By the same token, heat treated components are stored for production in the finishing section of the bearing lines during the following week. This feature also allows for change-over of sizes in a gradual manner so that there is never a need to stop the entire line.

Automatic Indexing

Machined cups are fed from the bins to a horizontal conveyer. The feeding rate is controlled by a photo-electric eye. A feeder conveys them to an elevator, one cup at a time. As they reach the top of the conveyer, they roll into a cage-type gravity chute. Here, the cups assume an upright position and roll toward an indexing feeder which alternately places a cup in each of two chutes leading into the revolving retorts in the carburizing furnace. Indexing is controlled by the cups actuating a Micro Switch as they roll toward the indexing device.

Time Clock Alternately Reverses Retorts

Both cups and cones are carburized to a depth of 0.030 to 0.046 in., depending on the part. This is done by heating at 1710° F. for 5½ to 8 hr. Furnace time is controlled by reversing the retorts at predetermined intervals, which are regulated by time clock settings.

The retorts have a single, built-in spiral device;

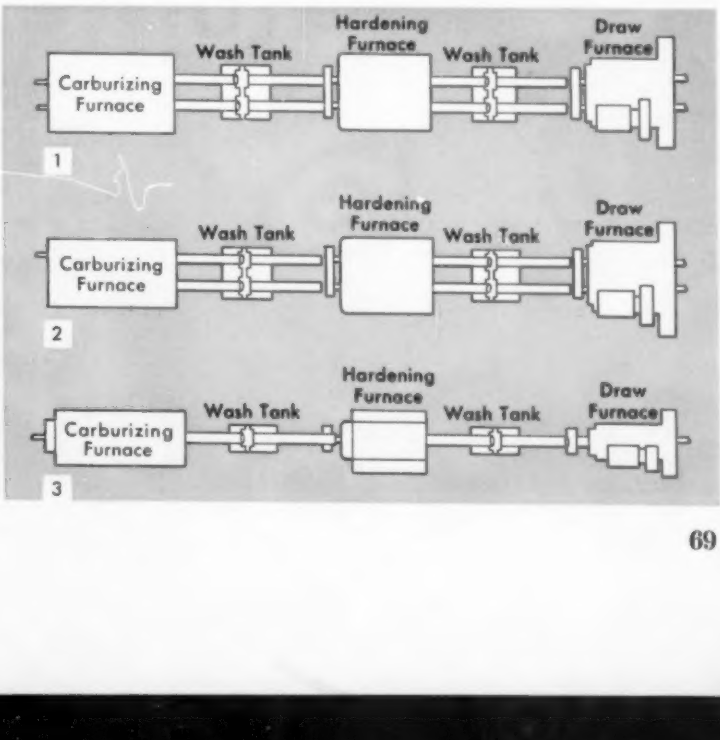


Fig. 2 – Two of the Three Cone (Inside Race of the Bearings) Lines Use Double Revolving Retorts in Each of the Carburizing and Reheating Furnaces. Dual conveyers permit these lines to operate as two separate heat treating operations

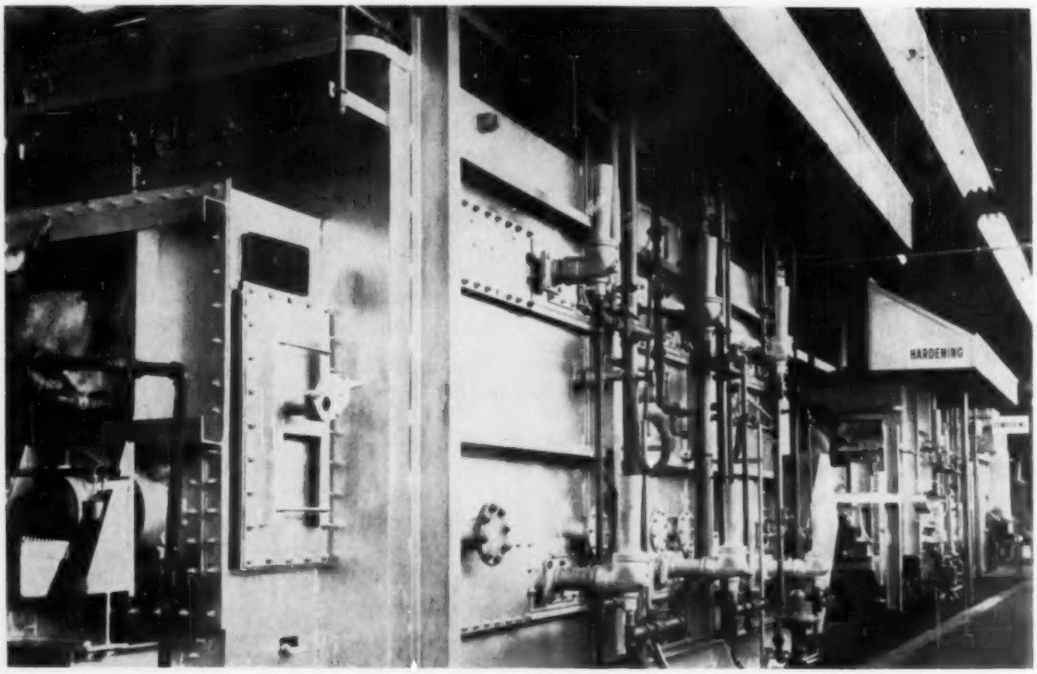
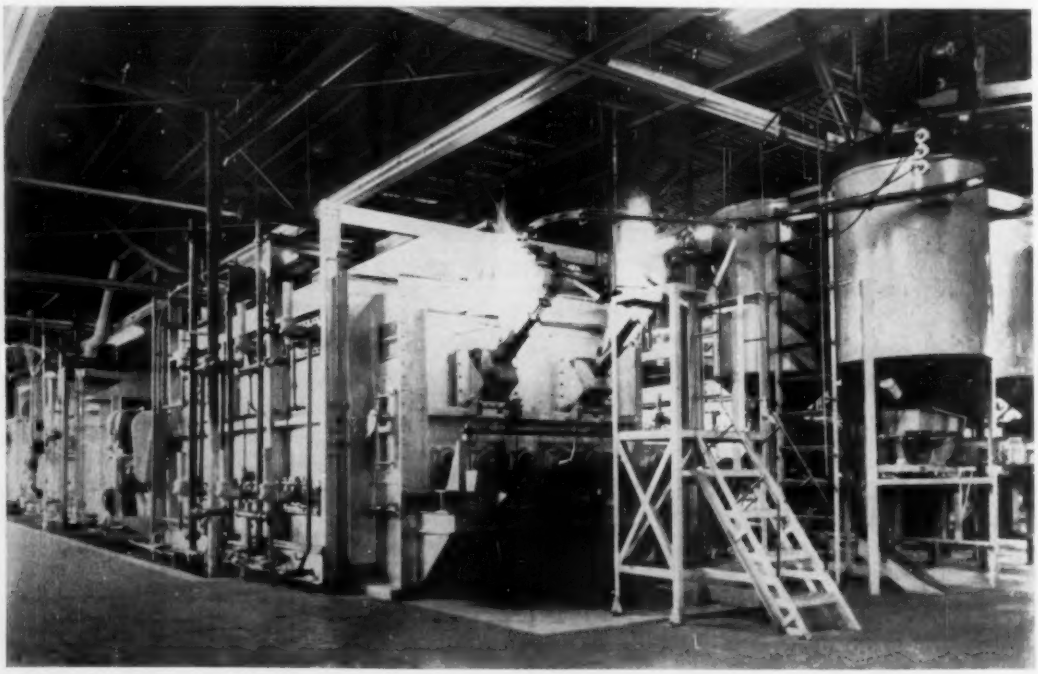


Fig. 3 – One Line of the Cone Heat Treating Section. Carburizing and hardening furnaces are heated with suction radiant tubes

Fig. 4 – Double Revolving Retorts Provide the Flexibility of Two Separate Lines. Each retort can treat a different part at the same time. Lower first cost and cheaper operation are realized from this type of heat treating line. Furnaces are fed from production stabilizing storage bins



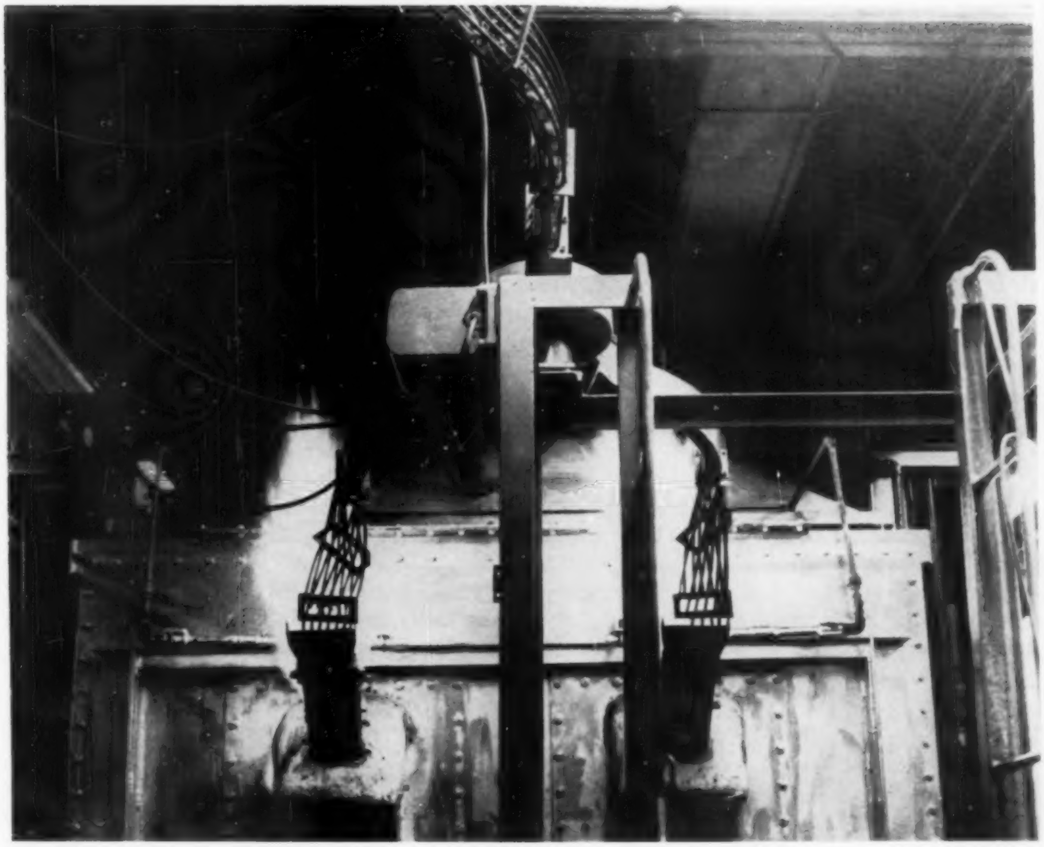


Fig. 5 – This Feeding Chute From One of the In-Process Storage Bins Automatically Meters Cups to an Indexing Device, Which Alternately Feeds First One Retort and Then the Other. Micro Switches (top center) control the indexing device

thus, by alternately revolving the retort slightly more in the forward direction than the reverse, the parts move forward at a speed to allow the furnace time needed to get the required case depth. This also keeps the parts continually in motion, which adds to case uniformity.

Timken holds the surface carbon level at 1% to give the best bearing life. This is done by using RX generator gas at a dew point of 10 to 25° F. as a carrier gas. A measured amount of natural gas is added to give the carbon potential for the required carbon level. Cups and cones can be treated at rates of 500 to 1100 per hr. depending on their size and weight.

Cups Are Oriented for Quenching

Parts drop from the carburizing furnaces into a quench tank. They are picked up by a rotary drum conveyer and carried through a spray washer which removes quenching oil. The cups are then automatically delivered to an orienting device which insures that the front face of each cup is in an "up" position. A vertical elevator lifts the cups to a feeder mechanism where they are dropped alternately, four at a time, into four of eight tracks leading into the hardening furnace. Pushers alternately move four cups out of the furnace into recesses in the platen of a hydraulic press.

The press automatically lowers four plugs into the cups. A split second before the plug makes final contact with the cup, quenching oil (flowing at 200 gal. per min.) floods the cup. The plug is held rigidly to size which prevents distortion of the cups and keeps them at a uniformly close size. The quench time varies from 5 to 25 sec., depending on the cup size. After the plug quench, the press rises and the cups are automatically pushed into a tank for an additional quench cf 7 min.

The quench press is a double-action unit. The main ram delivers a pressure of 800 psi. The ram moves a crosshead into which are fitted four cylinders holding the four plugs. The plugs first make contact with the cups, then the main ram takes up the slack in the plug cylinders and applies the full pressure.

The main housing and the plug cylinders are interlocked by Micro Switches in such a manner that should any single plug make contact with a cup before the rest of the plugs, the main cylinder will reverse itself and will not return until it has been reset manually. This prevents any mishaps should a cup not be in the exact quenching position.

Tempering

After the final quench, cups are removed by a rotary drum conveyer and transferred to a rotary drum spray washer to remove oil. From the washer, the cups are passed to the tempering furnace where final hardness is attained. An inclined elevator conveys the cups to storage bins for the final finishing operations.

All bearing components require the same hardness and carbon level, which means that temperatures are the same for each set of operations. Carburizing is at 1710° F. with surface carbon held to 1.00%. All carburized parts are oil quenched and develop a hardness of Rockwell C-65. Parts are reheated to 1510° F. and either drop quenched or press quenched as required. As-quenched hardness is C-62 to 64. Tempering is at 350° F., to give a hardness of C-58 to 62.

Auxiliary Equipment

Quenching oil is recirculated from a central system housed in the basement of the heat treating department. Oil is pumped from the main storage tank (located outside the building) through filters and heat exchangers which keep it at 110° F. It is pumped to all of the quench tanks (bearings which operate the revolving retorts are also cooled by this oil system) and constantly reflows back into the system. The overflow of oil returns to the main storage tank outside.

Fig. 6 – Perforated Drum Conveyers Transfer Work From the Carburizing Quench Through the Washers Into the Hardening Furnaces. This type of conveyer gives good oil drainage and has a wide load range

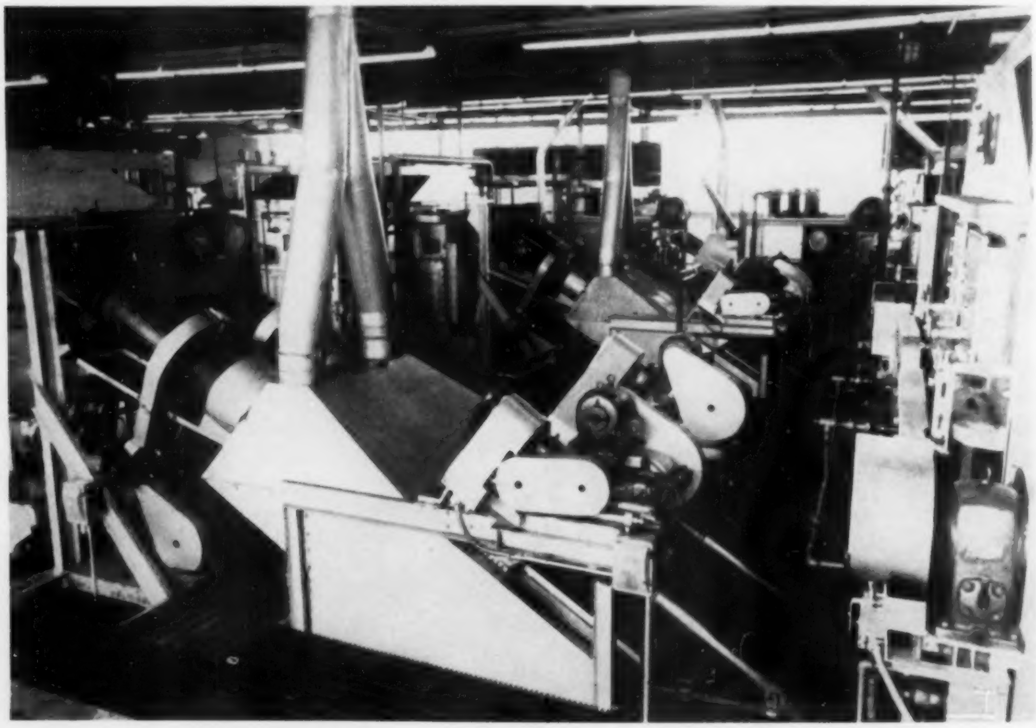
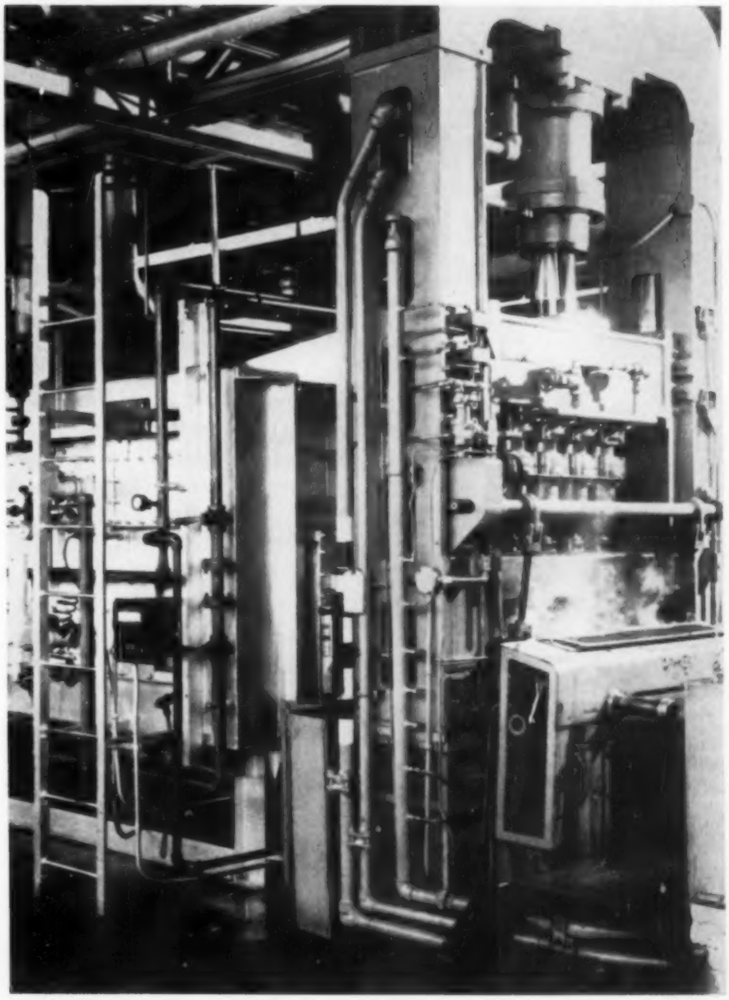


Fig. 7—Cups Are Plug Quenched to Maintain I.D. and to Minimize Distortion. The automatic press shown above quenches four cups every 5 to 25 sec., depending on their size. The double-action press is protected by safety devices against any misalignment of cups



Temperatures are controlled by Leeds and Northrup round-chart recording controllers. They are banked at central locations in each of the two heat treating departments. Round-chart type instruments are used to facilitate the keeping of daily records. Temperature control instruments are integrated into the same panelboard with the main control switches for each line.

Tool Life Is Increased

In addition to the high production achieved by this heat treating setup, other advantages have been gained. Hardening plug life has increased from 1000 pieces per grind in an older plant to 22,000 to 60,000 per grind, in the various sizes of cups. This is due to the more consistent size of the green parts and to the cleaner surface of parts coming from the furnaces. More uniform carburizing and better size control in machining and heat treating have cut minimum grinding stock from 0.005 in. in a previous setup to 0.0025 in.

Life of furnaces has been greatly extended due to the elimination of cyclic cooling and heating. Complete elimination of floor-type handling, such as trucks and overhead cranes, has lessened housekeeping problems to the point where the heat treating department has reached a cleanliness level comparable to that of the laboratory. The working force in heat treating consists of five attendants on each of three 8-hr. turns. Their responsibilities include sampling, testing, watching warning lights, and monitoring the control instruments.

Producing for the Supersonic Age

PH Stainless for Hot Airframes

*By R. W. WHITE**

Thermal problems of airframes which arise from aerodynamic and engine heating are becoming more severe. Sheet materials getting the most consideration for applications in skins and subsurface components are precipitation hardening stainless steels and titanium alloys. Use of PH stainless in aircraft and missile structures is increasing and the future is expected to bring many more applications. Ease of fabrication is a big point in their favor. (T24a, 17-57, J27; SS, 4-53)

EVEN THOUGH the exact speeds of our advanced airplanes and missiles are a military secret, the ever-increasing thermal problems which arise from aerodynamic and engine heating are well known. At high service temperatures the strength of structural materials is reduced; this complicates their selection.

The high-strength low-density materials, such as aluminum and magnesium-based alloys, are restricted in maximum temperatures at which they have useful load-carrying abilities. Maximum service temperature for aluminum alloys is in the 300 to 400° F. range, while that for magnesium alloys is somewhat higher. Thus, for many airframe applications where elevated temperatures are encountered, the aircraft and missile manufacturers have turned to other metals.

Sheet materials receiving major consideration for such applications as skin and substructure components are titanium alloys and precipitation hardening stainless steel. Other sheet material which could be given reasonable consideration for high-speed aircraft structures include low-alloy hardenable steels; standard chromium-nickel stainless steels; martensitic stainless steels; hot work toolsteels; superalloys and some of the more exotic alloys. Some of the limitations of these metals will be discussed.

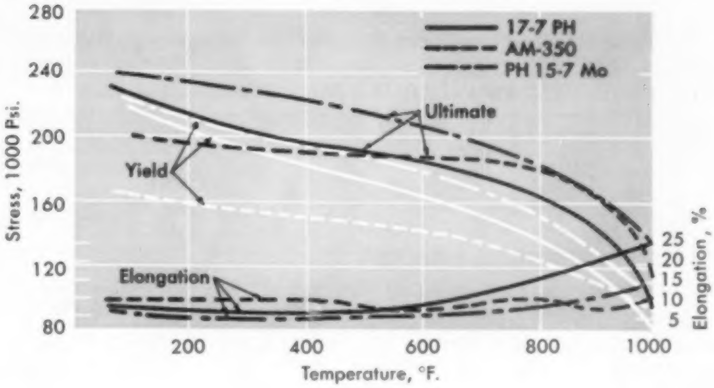
*Lead Structure Materials Engineer, Chance Vought Aircraft, Inc., Dallas, Tex. Adapted from a paper presented at a Symposium on Sheet Metals for High-Temperature Service held at the Southwestern Metal Congress, Dallas, May 12, 1958.

Table I – Precipitation Hardening Stainless Steels

Steel	Composition							
	C	Mn	Si	Ni	Cr	Mo	Al	N
17-7 PH (Armco)	0.07	0.60	0.40	7.0	17.0	—	1.15	—
PH 55-7 Mo (Armco)	0.07	0.60	0.40	7.0	15.0	2.25	1.15	—
AM-350 (Allegheny Ludlum)	0.10	0.90	0.40	4.0	17.0	2.75	—	0.10
AM-355 (Allegheny Ludlum)*	0.13	0.95	0.50	4.0	15.0	2.75	—	0.10

*Sheet material now under development

Fig. 1 — Typical Tensile Strength of 17-7 PH, PH 15-7 Mo and AM-350 in the Subzero Cooled and Tempered Condition

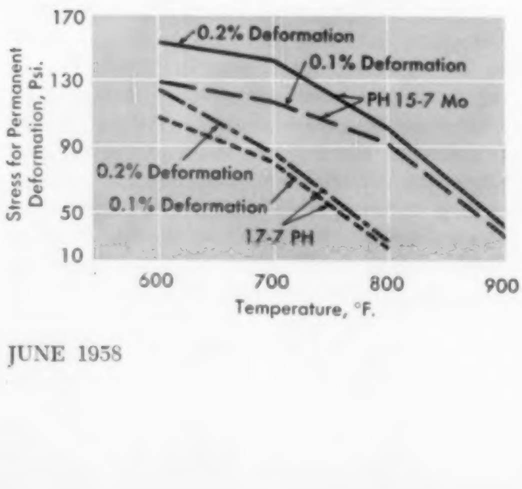


The low-alloy steels, in general, can be hardened to high strength levels but have these disadvantages: *(a)* They distort on quenching from high temperature, *(b)* corrosion resistance of this group of alloys is inadequate without surface protection, and *(c)* welding and machining are difficult in the hardened condition.

The standard chromium-nickel stainless steels (300 series) have found many applications in aircraft power plants and for airframe components. However, since their ultimate strength is obtained by cold reduction, forming properties do not allow sufficient freedom in design and they are only used in applications where mild forming is required.

The martensitic stainless steels (the 400 series and its modifications) are relatively new to the airframe industry. These alloys can be heat treated to provide high-strength properties at elevated temperatures, but corrosion resistance is not adequate for aircraft requirements. The following production problems are associated with these steels: *(a)* warping in heat treatment, *(b)* decarburization, *(c)* machining, and *(d)* welding difficulties. Considerable work is in progress on development of new martensitic steels and improvements can be expected soon.

Fig. 2 — Deformation Behavior of PH 15-7 Mo and 17-7 PH Sheets in Condition RH 950 Under 1000-Hr. Load



Hot work toolsteel has the highest strength-weight ratio between 400 and 1000° F. of any commercially available structural metal. Production problems associated with the toolsteels are similar to those for low-alloy and martensitic steels. Corrosion and oxidation resistance is inadequate and parts would require a protective coating. Considerable development work in this area is under way.

Superalloys will receive little consideration as a sheet material for service below 1000° F. because of the use of strategic alloying elements such as nickel and cobalt.

Material Requirement

Before any material can be considered for a specific application, the predicted service conditions such as loads, temperature, time and environment must be defined. The first requirement for any aircraft is light weight. This means that a high strength-weight ratio must be maintained at the predicted service temperature. The second requirement is that of space or thickness. If only a certain amount of space is available for a component, a material must be chosen that will impart the necessary structural integrity to the part in that space.

Room-temperature properties are important, since the strength, hardness, ductility, and fatigue strength indicate the quality and uniformity of the material. Elevated-temperature properties such as strength, creep, deformation, stress-rupture, and fatigue determine the stability and behavior at the service temperature.

Corrosion, oxidation, and wear or erosion resistance are other important properties which can affect the strength of sheet material. In-

Table II – Heat Treatment Procedures for Precipitation Hardenable Steels

17.7 PH and PH 15-7 Mo (Mill Annealed at 1950° F.)

Subzero Cooling Treatment (RH 950)	Double Aging Treatment (TH 1050)			
1. Heat to 1750° F., 10 min. 2. Cool to −100° F., hold for 8 hr. 3. Heat to 950° F. for 1 hr. 4. Air cool	1. Heat to 1400° F. for 90 min. 2. Cool to 60° F. within 1 hr. 3. Heat to 1050° F. for 90 min. 4. Air cool			
Typical Properties	RH 950		TH 1050	
	PH 15-7 Mo	17-7 PH	PH 15-7 Mo	17-7 PH
Ultimate strength, psi.	240,000	235,000	210,000	200,000
Yield strength (0.2% offset)	215,000	220,000	200,000	185,000
Elongation in 2 in.	6%	6%	7%	9%

AM-350 and AM-355 (Mill Annealed at 1950° F.)

Subzero Cooling Treatment (SCT)	Double Aging Treatment (DA)			
1. Heat to 1710° F. 2. Cool to −100° F., 3 hr. min. 3. Heat to 850° F., 3 hr. min. 4. Air cool	1. Heat to 1375° F. 2. Air cool 3. Heat to 850° F. 4. Air cool			
Typical Properties	Subzero Cooling Treatment		Double Aged	
	AM-355	AM-350	AM-355	AM-350
Ultimate tensile strength, 1000 psi.	215,000	200,000	190,000	195,000
Yield strength (0.2% offset), 1000 psi.	195,000	175,000	170,000	155,000
Elongation in 2 in.	12%	13%	12%	10%

adequate surface stability, such as scaling, pitting and intergranular attack, may reduce the strength so much as to cause premature failures.

Regardless of the outstanding properties of an alloy, the material must be available in all forms required to be useful in a production airplane. Ease of fabrication strongly affects the real value and selection of the material. Weldability and formability are factors which must be considered in practical applications.

PH Stainless Steels

Keeping these requirements in mind, let's look at some of the precipitation hardening stainless steels. Nominal compositions and sources are given in Table I. These steels differ from conventional steels in that they retain much of their hot strength when exposed for long periods at 400 to 800° F.

The 17-7 PH is one of the oldest of the currently used commercial precipitation hardening steels; PH 15-7 Mo is a relatively new alloy. Higher strengths and better elevated-temperature stability are achieved by addition of 2 to 3% Mo. The strength of these steels depends upon two factors: *(a)* the transformation of austenite to martensite and *(b)* partially on the precipitation of a second phase (probably aluminum-nickel) from the martensitic matrix.

The AM-350 and AM-355 types are not true precipitation hardening steels but are so classified because they are hardened and softened by similar heat treating schedules. They depend on a martensitic transformation to achieve their strength. Since there is no secondary hardening, they have lower strength at room temperature than 17-7 PH and PH 15-7 Mo; however, at around 500° F. the strength of the steels tends to equalize.

Typical heat treatments used for these alloys are given in Table II. They are purchased in the high-temperature anneal (1950° F.) condition to give austenitic stability during shipment and maximum formability. When subzero treatment is contemplated, it is necessary to condition the material. Response to the subzero cooling and tempering treatment is obtained by a conditioning treatment at about 1750° F. Double aging can be done without conditioning the mill annealed material.

The strength of the subzero treated steels is higher than that of the corresponding double aged steels. This is due to retention of more carbon in solid solution in the austenite prior to transforming into martensite. Typical tensile strengths obtained with 17-7 PH, PH 15-7 Mo, and AM-350 in the subzero cooled and tempered condition are shown in Fig. 1. Note that the tensile strength of the steels tends to equalize at around 500° F.

Load Carrying Ability – An important design consideration in the use of materials above 600° F. is their load deformation behavior. Figure 2 shows the relative capacity of 17-7 PH and PH 15-7 Mo steels to withstand loading for 1000 hr. in the range 600 to 900° F. No more than 0.1% and 0.2% permanent deformation results. Creep properties of PH 15-7 Mo are superior to those of the original 17-7 composition. AM-355 also has better creep strength than AM-350.

In general, the PH steels are adequate in regard to notch sensitivity, bearing strength, impact strength, weldability, formability and machinability. While these alloys have been classified as corrosion resistant materials, a more adequate classification would probably be delayed corrosion resistant materials. Specimens exposed to harsh marine atmospheres show superficial red rust after a short time. Their stress-corrosion characteristics are another important consideration, at certain stress levels and environment, but only limited data are available.

Applications of PH Sheet Alloys

The first major use of these steels was for ribs and stringers in the F-86 Sabre Jet airframes. Good fabrication experience and service performance has led to its use in other high-speed aircraft. Currently, PH alloys are being used as structural parts in the F-100, F-102, F-104 and F-105 fighters and in parts for the B-52 and B-58 bombers. Structural parts used for aircraft and missile applications are such standard items as stringers, ribs, bulkheads, longerons, shrouds, honeycomb, and skins.

In the design of an advanced Chance Vought aircraft, one of the areas where a problem existed was a bulkhead in the aft section. Although a titanium alloy had been used for this application, higher temperatures required that it be beefed up to maintain the required strength at the service temperatures to be encountered. Because of a space restriction in this area, titanium could no longer be used for this application. Since previous experience had been gained with 17-7 PH, this alloy was considered for the bulkhead. Its over-all size is about 4 ft. in diameter; total weight is about 150 lb. This bulkhead is made up of 59 stainless steel details ranging in gage from 0.032 to 0.156 in. The details are assembled using standard stainless steel rivets. This bulkhead determines the form of the fuselage, provides a support for fastening the stringers and skins, and sustains the load of the fin beam and vertical stabilizer.

Processing

As used at Chance Vought Aircraft, 17-7 PH is purchased in the mill annealed condition (1950° F.) to MIL-S-25043 specification. It is processed and heat treated according to the end use or fabrication requirements. The procedure for the two-stage heat treating method (TH 1050), which has been successfully used for producing the aft bulkhead parts, is as follows:

1. Preform part from mill annealed (Condition A) material. Forming is done on the rubber press by the Guerin process. Contour and definition are good except for minor buckling (Fig. 3) of the outer shrink flange.
2. Hot form at 1200° F. for 10 min., if part is not well defined. Buckles created above have been removed and the part has good definition and contour.
3. Harden to Condition T (heat treat at 1400° F.) for 1½ hr.; cool to 50 to 60° F. in 1 hr.
4. Hot form again with heated die used in step No. 2, at 1050° F. for about 10 min. to remove warpage caused by step No. 3. (Note that heating above 1050° F. or heating other than furnace heating, as required by step 5 (below), for more than 15 min., at any one time, after the 1400° F. treatment will critically reduce strength of the finished part. Furthermore, the part is not to be heated, other than furnace heat treatment, for more than a total of 30 min. after the 1400° F. heat treatment. If the part is exposed to temperatures over 1050° F. after the 1400° F. treatment, the part must be re-annealed and re-heat treated.)
5. Temper to condition TH 1050 (heat treat at 1050° F. for 1½ hr. and air cool).

In the event that excessive warpage is found after step 5, the parts can be re-hot formed at 1050° F., according to step 2. Production experience reveals that this additional forming is seldom required.

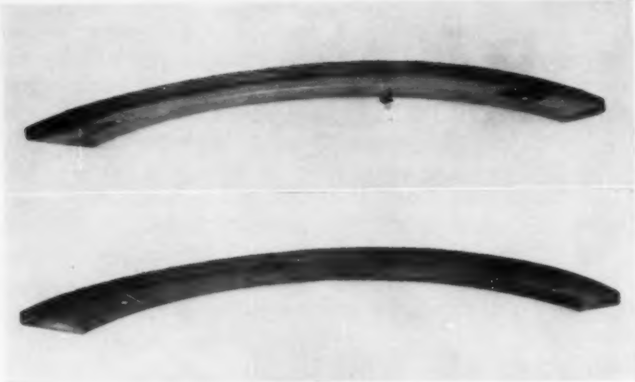


Fig. 3 – This Bulkhead Part (Top) Is Formed From 17-7 PH on a Rubber Press by the Guerin Process. Contour and definition are good except for minor buckling on the outer shrink flange. This is corrected by hot forming before hardening to give part below

The steps in the method which uses refrigeration and tempering (RH 950) are as follows:

1. Preform part from annealed (Condition A) material and hand form to eliminate any excessive buckles. (Note: Hand forming may be done at any time prior to final heat treat.)

2. Anneal to condition A 1750 (heat treat at 1750° F. for 10 min.) There may be slight warpage in the web of the part.

3. Condition R-100 (cool to −100° F. and hold at this temperature for 8 hr.).

4. Age to condition RH 950 (heat treat at 950° F. for 60 min.). Unacceptable warpage may exist in the web and flange.

5. Hot form at 950° F. as required (maximum time limit for this operation is 20 min.). The part shown in Fig. 4 now has the required mechanical properties with good definition and no warpage.

Other processing required is removal of any surface contamination caused by heat treating. Liquid honing is a satisfactory way to remove surface contamination. Scaling has been found to be limited and can be removed by sand-blasting if the material is of a heavy enough gage to withstand it.

A comparison of the two methods of forming reveals the following:

1. Both processes produce acceptable parts.

2. Less distortion is produced by the refrigeration and tempering (RH 950) technique.

3. Tooling requirements are identical for both methods.

4. Additional facilities (refrigeration) are required for the RH 950 technique.

5. There is less chance of error in shop practices for the RH 950 treatment.

6. Intermediate stage re-forming is more expensive and time consuming for the TH 1050 technique.

Predictions – With the development of the newer precipitation hardening stainless steels, PH 15-7 Mo and AM-355, many more applications will be realized for these alloys. Maximum service temperature may be increased by another 200° F., allowing more freedom in design.

Fig. 4 – This Part Made of 17-7 PH Is Processed by Refrigeration to 100° F. Below Zero and Aging at 950° F. for 60 Min. Final step is re-hot forming at 950° F. to remove any warpage

Producing for the Supersonic Age

Materials for Rocket Engines

*By R. C. KOPITUK**

Rocket engine components are subjected to high stresses at high temperatures. Since the fuels are often corrosive, the materials, both metallic and ceramic, must have great endurance. Selection and fabrication of materials for both regenerative and nonregenerative rocket engines are discussed. (T24b, T2p, 17-57; SGA-h)

THE FANTASTIC POWER needed to propel the Sputniks and their American counterparts can only be attained by rockets – but such rockets as were never imagined by their Chinese inventors. When you consider that extremely active fuels, such as liquid anhydrous ammonia and hydrazine, with oxidizers such as liquid oxygen, red fuming nitric acid and liquid fluorine, are used to drive the rocket engines and that temperatures up to 6500° F. are reached during the blast, you can see that the selection of materials for their construction presents difficult problems.

Let's begin with a general illustration of a liquid propellant system. While there are many variations of this engine (illustrated by Fig. 1), the temperature ranges shown are similar for all types.

The operation of this engine, in particular, the fuel flow, is an important point. The oxygen and fuel are pumped into the mixing area where they are ignited; the fuel (in the regenerative-type system shown) cools the combustion chamber lining before reaching the injector head. The pump is operated by a turbine wheel, which in turn is actuated by a gas generator powered through offshoots of the main fuel lines.

Environment Gives Materials Problems

There are several "hot components" in a rocket system. These are the turbine wheel, gas generator, injector head, combustion chamber, and chamber extension cone. In choosing a material for any of these, many factors (such as oxidation resistance and strength requirements, corrosion and erosion resistance, fabricability, availability and cost) have to be considered. The conditions usually vary widely. However, one thing relatively common to most components is the duration of the operation. Because total

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firing time is usually short, engineers are concerned only with short-time properties – 10-hr. rupture strength, 10-min. yield strength, impact loading, and short-time fatigue strength.

The turbine disk and blades in most rocket designs offer relatively few problems. Although they operate under extremely severe loading conditions and high thermal shock, they are not heated over the 1500 to 1600° F. mark. This is because they are subjected to off-mixture combustion products from the gas generator. Furthermore, they operate for only short periods.

The gas generator is generally the next hottest area. Here, metal parts usually do not exceed 1900° F. This is a cylindrically shaped component, closed on one end by fuel and oxidizer injectors, and open at the other for emission of the combustion gases. Invariably, it is made of thin welded sheet. If operated above 1600° F. for a service life under 30 sec., an insulating ceramic coating may be used to realize the high strength potential of lower-temperature alloys. If operating life is over 30 sec., the generator wall is usually not insulated. One reason is that the added weight of insulation needed to keep the temperature down would be excessive. Due to the highly turbulent and radiating characteristics of the combustion gases, the generator walls with a thin ceramic coating come up to operating temperature rapidly. When the operating temperature is reached, the ceramic acts as so much excess baggage. In a rocket engine system, 1 lb. of construction material can mean the loss of 25 to 50 lb. of payload. Only when improved oxidation and corrosion resistance is required is a ceramic coating (usually a high-temperature enamel) used. Where nonprotected metal is used, it is generally Type 309 or 310 stainless steel.

Problems With Molybdenum

For longer running times – from 10 min. to several hours – molybdenum alloys have been considered, but they have certain major disadvantages. For one thing, they become quite brittle when welded and with the stresses and high vibrations of a rocket engine this could prove disastrous. Furthermore, the ductility of the joints gets worse below 60 to 120° F., and most engines are required to start satisfactorily as low as – 65° F. In rocket engine systems, large pressure rises are quite often clocked in milli-seconds and the initial surge of pressure at this temperature would undoubtedly cause trouble in the welds. Recent work has improved ductility but even so it's nowhere near what's needed. As for the oxidation resistance, a really suitable coating has yet to be found.

Metals which have been used or considered for use in the gas generator are the low-alloy steels, 300 series stainless steels, Inconel, Inconel "X", A-286, and R 235. Among the ceramic coatings are alumina (Al_2O_3), zirconia, NBS coating, and Solaramic. In addition, aluminum dip and certain high-temperature metallic coatings have been used.

To sum up: The main requirements for a gas generator material are oxidation resistance and strength at temperature, along with fabricability.

Injector Head

As its name implies, this component injects the propellants into the combustion chamber. Usually in the form of a hemisphere or short cylinder capped on one end and open to the thrust chamber on the other, the injector head may be mechanically attached to the chamber by bolting, clamping or welding. It can also be an integral part of the thrust chamber design. Good corrosion resistance and high strength are necessary in this item. Temperatures encountered, for the most part, are ambient which could mean +165° F. (for fuels such as hydrocarbon mixtures, aniline, butyl mercaptan), or –290., –320., or –420° F. for liquid oxygen, nitrogen or hydrogen, respectively. The one hot area faces the combustion chamber. Although combustion occurs somewhat downstream of the injector and the latter is cooled by the propellants flowing through it, the severe turbulence of the gases can heat local hot spots to 2400 or 2500° F.

The injector head is usually welded; sheet metals from 0.015 to 0.125 in. thick are employed. Several factors must be considered in selecting the materials. High strength is required for the outer case and oxidation resistance is needed in the injector face. Also necessary is resistance to the corrosive propellants passing through the head and to the moderately high temperatures on the inside surface of the injector face wall.

The corrosion problem is not too bad when we consider most of the common fuels and some oxidizers. However, when one gets into some of the more active propellants – such as white fuming nitric acid, red fuming nitric acid-HF inhibitor, liquid fluorine or 90% hydrogen peroxide – conditions get more severe. Since the fuels and oxidizers are highly reactive, they must be separated from one another by leak-tight par-

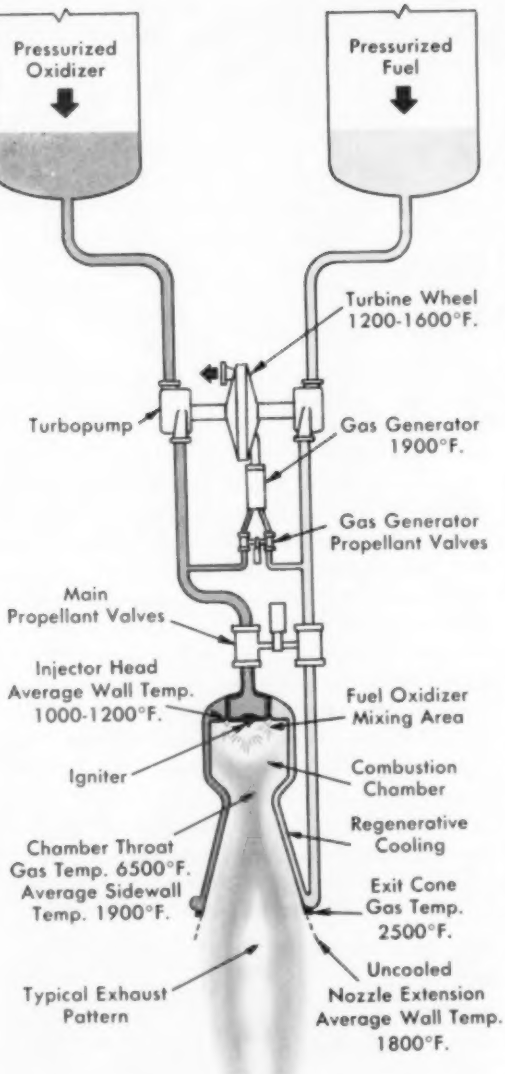


Fig. 1 – General View of Regenerative-Type Rocket Engine. Temperatures are representative of what materials must withstand in many rocket applications today

titions in the injector. The smallest leaks can cause severe explosions destroying the engine. One trick which has been used to seal weld beads is to coat them with an acrylic slurry of a high-temperature nickel brazing alloy, then fuse at a higher than normal flow temperature (for pinhole penetration) in a suitable atmosphere furnace. Where a casting is not feasible because of design complexity, the materials must be readily formable, and weldable or brazeable.

After fabrication is complete, it is often necessary to heat treat (by precipitation hardening or air hardening) to minimize warpage in the assembly. The obvious question after examining all the requirements: Do we have any materials which will fit the bill? Surprisingly, the problem is not as complicated as it sounds. By carefully examining the corrosion time, temperature and fabrication parameters, several material combinations can fit a specific application. Materials vary considerably, depending upon the propellant combination, length of running time, number of firing cycles, strength requirements, and other factors. They range from the low-alloy steels, through the 300 stainless steel series, and on up into the superalloys such as A 286 and Inconel "X". Insulating ceramic coatings, such as alumina and zirconia are also used on the injector face. Corrosion resistance, strength and fabricability are generally the prime factors to be considered when recommending material for this component.

Combustion Chamber Extension Cone

This is usually a truncated cone welded or mechanically attached to the end of the combustion chamber. Its function is to develop more thrust from the expanding gases spurting from the combustion chamber; it becomes more efficient at higher altitudes. This component is generally uncooled and is usually made of welded sheet. Though the temperature of the expanding gases decreases considerably and pressure is a minor consideration, the gases are still quite hot (around 1600° F.) and tend to form stagnation or turbulence patterns causing local hot spots reaching 2200 to 2500° F. When the combustion gases are highly oxidizing, "burning" of the metal occurs. Furthermore, the gases are moving at a high speed. This means that erosion, particularly as it concerns the "hot spots", is an important factor. Many sheet materials – from mild steel to the high alloys – have been evaluated along with various metal, cermet, and ceramic protective coatings. The success of these materials and coatings depends in part on the injector design, which in turn affects the gas pattern. The corrosive characteristics of the gases is also an influence. Fabricability, erosion and corrosion resistance are the major factors to consider when recommending a material for the extension cone.

The Combustion Chamber

This is the heart of the rocket engine. Actually, the complete chamber consists of three

major parts: *(a)* the injector head which closes one end, *(b)* the extension cone which is open at the other end, and *(c)* the combustion chamber in between. The combustion chamber is cylindrically shaped with a necked-down section (usually referred to as the nozzle or throat area) about ⅔ the distance from the injector face. Propellants enter the cylindrical portion where they mix and react in what might be termed a continuous explosion. Since one end of the chamber is closed by the injector head, the gases squeeze through the relatively narrow throat opening on the other end, picking up speed as they do, and expand out past the divergent section of the throat and the extension cone. The resultant force of these gases moves the plane or missile ahead.

The combustion chamber is generally exposed to all the conditions to which the other "hot" components are exposed, but more so. Temperatures are high and erosion is extremely severe. Both oxidizer and fuel can be corrosive. Fabrication can be quite complicated, depending on the design, and high strength with light weight is almost always a requisite. With all these factors to consider, the combustion chamber presents some complex problems.

Two Types of Chambers

Basically there are two types of liquid propellant rocket chambers: *(a)* the uncooled, for short-time firing, and *(b)* regeneratively cooled, for extended or repeated use. The uncooled chambers (Fig. 2) are usually ceramic-lined. Metals used have ranged from the low-alloy steels such as 4130, 17-22 AS, 4335, to the more highly alloyed materials such as 300 series, A 286, and Inconel "X". Titanium has also been considered. Low-alloy steels and titanium are used for their high strength-to-weight ratio where the final metal temperature will not go much above 1000° F. Reduction of critical materials is, of course, another attraction of the low-alloy steels.

Fabrication of Jacket

Flanges are made from bar stock or forgings, while the outer shell is welded sheet, spun or press-formed to shape. Welding is usually performed by the tungsten-arc gas-shielded method. All processing is critical since the smallest leak cannot be tolerated in the chamber wall; otherwise, a hole several inches in diameter will form in a few seconds of operation.

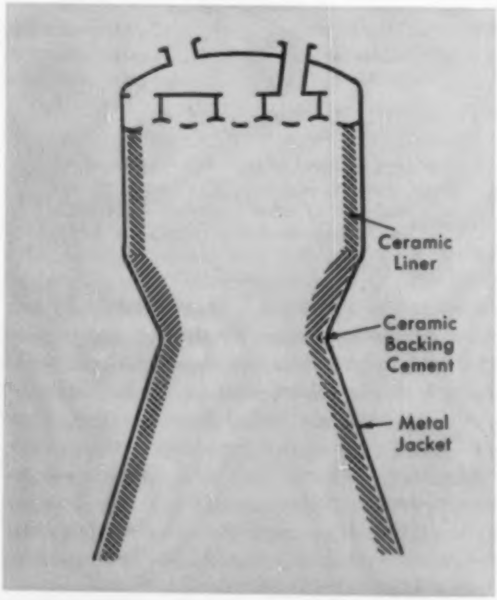
The part, after welding, is heat treated and coated for corrosion and oxidation resistance. Sometimes, as in high-temperature nickel alloy brazing or aluminum dipping, the coating process is part of the heat treatment. Where corrosion occurs in the uncooled chambers, aluminum dipping without subsequent diffusion, or electroless nickel plating, is quite satisfactory. If some oxidation and erosion resistance are also needed, as in the uncooled extension cone, a high-temperature nickel-braze coating is desirable. Generally about 0.010 in. of coating is applied.

Ceramics Are Important

Ceramic materials are almost always used for the uncooled thrust chamber lining to maintain low metal temperatures. Although there has been considerable effort on ceramics of late, much work is still required to improve the old ones and to develop new ones. There are basically two ceramic classes: the insulating type and the oxidation resistance type. Typical of the former are the ceramic bodies, ceramic bonding cements and some coatings such as alumina and zirconia. Typical of the latter are high-temperature enamels.

Insulating ceramic coatings are not used too frequently on uncooled liquid propellant chambers except for runs of very short duration.

Fig. 2 – Combustion Chamber of Nonregenerative-Type Rocket Engine Used for Short-Time Firing. Since the sidewalls are not cooled, they are ceramic-lined



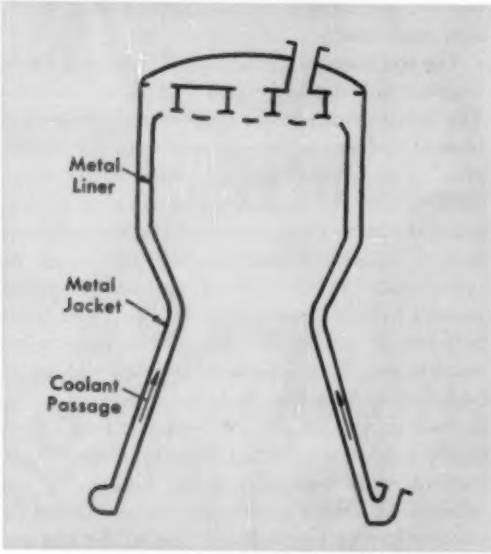


Fig. 3 — Diagram of Regeneratively Cooled Thrust Chamber. Either fuel or oxidizer can be used to cool the walls

However, they are frequently applied to the extension cones; oxidation resistant coatings may also be used.

Ceramic bodies and bonding cements are widely used for the lining. One of the big problems in fabricating uncooled chambers is the bonding and supporting of the ceramic bodies to the metal shell. Ceramic bonding materials should be readily pourable as mixed and should give good bonding strength, as set. Further, they must be able to withstand high vibration during operation and be resistant to the highly corrosive fuels. Some of the more common bonding cements are lumnite (calcium aluminate), foamed lumnite, lumnite and flint, plaster of paris, and alumina-base cermets.

Ceramic bodies used in liners and nozzles have had many compositions. They must have good refractory properties, good oxidation, corrosion, erosion, and thermal shock resistance. Further, they must be readily molded or machined into the shapes required. Designs make use of compressive strength of ceramic materials and are such that they are usually supported in tension by the outer metal shell. Some materials used are graphite, silicon carbide-coated graphite, carbon-bonded silicon carbide, silicon nitride-bonded silicon carbide and silicon carbide with a recrystallized silicon carbide bond. Even plaster of paris bonded with Weldwood glue has been used in short duration firings.

Cooled Chamber

In a regeneratively cooled thrust chamber (Fig. 3), the fuel or oxidizer passes between the outer jacket and the inner liner to cool the sidewall of the chamber. Combustion can reach 6500° F.; gas velocities go as high as 8000 ft. per sec. and over, in the divergent cone. A unit of this type generally has to run repeatedly. Length of time for a single run usually is 4 to 6 min. and total operating life can be as long as several hours.

Engines such as these are employed for the Bell X type planes, Douglas Skyrocket experimental rocket planes, and Viking missiles. The chamber is usually sheet metal and tubing construction. Wall thickness generally does not exceed 0.125 in. and can go as low as 0.010 in. Where wall thickness is low, wire or glass fiber wrapping is used for support on the outside diameter of the chamber.

From the corrosion standpoint, the welded construction materials contact such highly corrosive or reactive propellants as white fuming nitric acid, 90% H_2O_2, hydrazine, and liquid anhydrous ammonia, just to mention a few. Operation must be repeated many times, and there is always the possibility that, during engine layover, the materials will be subjected to dilute concentrations of propellant in blind holes or cavities. They must also resist the highly corrosive products of combustion on the gas side. This coupled with the high erosion and high temperatures encountered on the gas side, necessitates the use of highly compatible materials with good oxidation, corrosion and erosion resistance for the gas sidewall.

Oxidation Problems

Careful microscopic examination of various stages of metal oxidation failure in the throat area has revealed that, at temperatures above 1700° F., microscopic sections of oxide film are torn from the base metal by the highly erosive gases. A tiny, sharp edge remains and microscopic gas turbulence occurs here which gives higher local temperatures with accelerated oxide formation and removal. The wall thins, which leads to higher propellant temperatures. A drop in cooling efficiency by the propellant occurs; this further increases wall temperature. Finally, as severe nucleate boiling of the propellant occurs, the metal wall temperature rises rapidly and burns through. If base metals are already oxidation resistant, and if design changes cannot

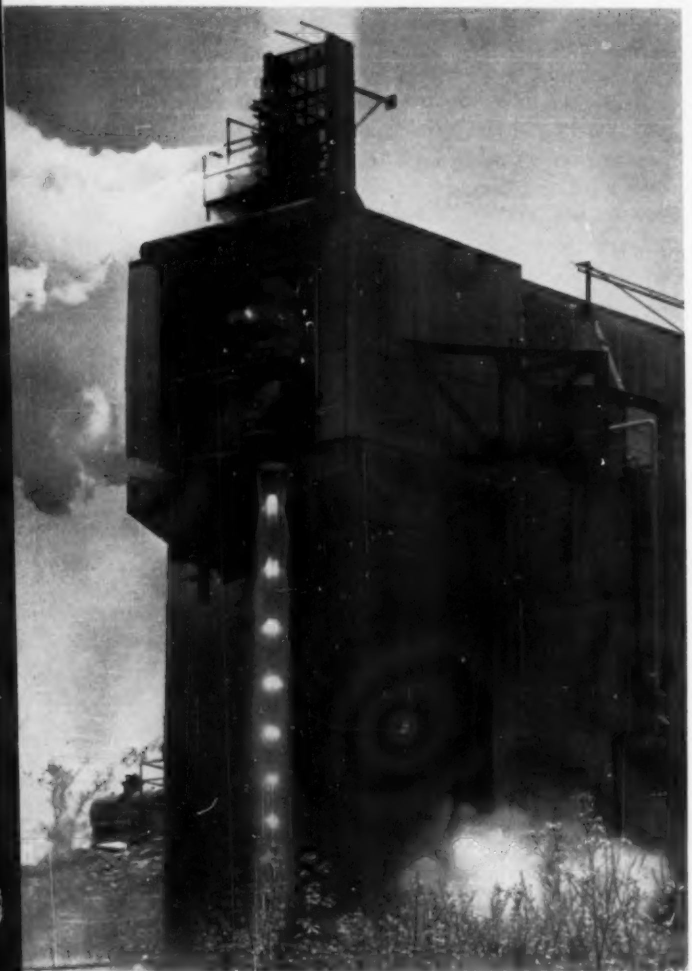


Fig. 4 – Test Firing a Rocket Engine

improve cooling, then the metal must be protected by a ceramic coating.

Some of the materials used for the chamber liners have been 300 series stainless steels, A 286, 17-7 PH, Inconel, nickel, Inconel "X", and some cast and wrought aluminum alloys. Where the lower melting or less oxidation resistant materials are used, the oxidation resistant or insulating coatings are employed.

Coatings for Protection

Some of the oxidation resistant coatings that have been used are Coast Metals 53 and 56 (these are the Ni-Si-Cr-B alloys) and Solaramic-type ceramic coatings. Insulation-type coatings include alumina and zirconia. As powders, these can be sprayed to a given thickness rapidly, but have the disadvantage of poor erosion resistance.

The rod form of alumina and zirconia is known commercially as Rokide A and Z, respectively. The latter materials are sprayed on grit or sand-blasted surfaces by the oxy-acetylene flame spray gun. The molten particles adhere to the roughened surface. These coatings have good insulating properties and excellent erosion resistance, though adherence and sealing still need improvement. A precoat of sprayed Nichrome powder helps somewhat. It is hoped that in the near future, through the use of composite metal-ceramic coatings, a molecular bond can be established. Also the Rokide-type coatings, as deposited, are 10 to 15% porous, requiring a highly oxidation resistant base or precoating to prevent rapid oxidation of the base metal and subsequent flaking of the ceramic coating at the ceramic-to-metal interface. Due to the low rate of application with this process, two to four guns are needed to complete one part in a reasonable length of time.

Problems Attacked in Many Ways

In our work, we have found that materials engineering aids not only in establishing materials and processes for construction of the rocket engines, but sometimes helps to establish operation characteristics. For example, not too long ago, a thrust chamber was built of 300 series stainless steel which, according to heat transfer calculation, should have operated with no protective coating on the gas side. To make a long story short, the throat burned through. Since the propellant, liquid anhydrous ammonia, permitted a low-alloy steel for test purposes, Type 1020 steel was substituted. Again, the chamber was run, and as expected, it burned out in about the same time.

Microscopic examination of the cylindrical portion revealed a martensitic structure (about Rockwell C-34) in place of the original annealed ferritic structure. Since the run lasted only 12 sec., it was necessary that the metal rise to an austenitizing temperature, have carbon go into solution, and be quenched in 12 sec. to get this structure. With this in mind, and after further examination of the metal oxide film, it was estimated that metal temperature had been about 1800° F. in what was supposed to have been a 1300° F. area. This indicated that 300 series stainless steel would do the job, provided the propellant passages were redesigned to increase flow velocity and improve cooling.

Staff Report

The All-Basic Openhearth

With hearth and walls already being constructed of basic material, the only area left to complete the all-basic openhearth is the roof. Work conducted by American and British steelmakers over the last few years indicates that higher production and longer roof life can be expected when problems imposed by the use of basic brick are solved. (W18r, D2, 1-65; RM-h, ST-e)

Minor matters like recessions never stop steelworkers from getting together to swap ideas. As a consequence, the A.I.M.E. Openhearth and Blast Furnace Conference, scheduled several months ago when business was better, came off as planned. Over 1500 attended the session in Cleveland to discuss subjects such as charging methods, exothermic ferromanganese ladle additions, bottom practice, oxygen steelmaking and basic roofs. Methods for producing more steel at faster rates generated a large amount of interest. For instance, the session on basic roofs filled the meeting room. Here, when the bugs are worked out, is a scheme which will ensure higher steelmaking rates.

As everybody familiar with usual openhearth furnace knows, the hearth is composed of the basic materials, magnesite and dolomite, while the roof is constructed of silica brick. Since magnesite and chrome-magnesite brick are also used for the walls, the only item needed for an all-basic openhearth is a basic roof. In the past, silica brick has been the favorite roof material because of its low cost (about one third as much as magnesite brick) and high strength. It also has much greater resistance to spalling.

However, serious limitations on firing rates are imposed by the low melting point of silica which is only 100° F. above that of molten steel. Consequently, during meltdown periods, the flame has to be adjusted so that it will melt only the scrap and not the roof as well. Basic brick, with its higher melting point, withstands higher firing rates. This means that meltdown is much faster, and production is increased appreciably.

Production

A typical example of the progress being made in basic roofs is the data presented at the meeting by M. H. Stadler, Jr., of U.S. Steel Corp. The South Works, in Chicago, has had an all-basic openhearth furnace in operation for 10½ years. During this period, the unit has consistently produced more tons per operating hour than have similar silica brick-roofed openhearths in the same shop. Figure 1 illustrates the general trend during the 14 campaigns in this furnace.

Since higher flame temperatures are possible when the furnace is roofed with basic brick, it might be expected that fuel consumption would be higher for each ton of steel produced. This proved to be the case; however, by reducing

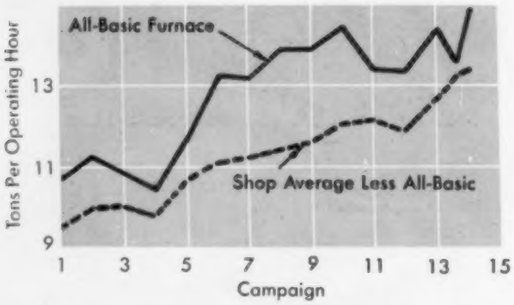


Fig. 1 — All-Basic Furnace Production Compared With Shop Average at South Works, U.S. Steel Corp. The production of the all-basic openhearth is consistently higher

air infiltration in the slag-pocket areas, fuel consumption was reduced considerably. As of last report, the basic furnace used 3,987,000 Btu. per ton, while the average silica-roofed furnace used 3,991,000 Btu. per ton. In the important factor of roof life — which greatly affects maintenance problems — the basic roof usually lasts two to three times as long as a silica roof. This is shown by the graph of Fig. 2 which compares the two roof types.

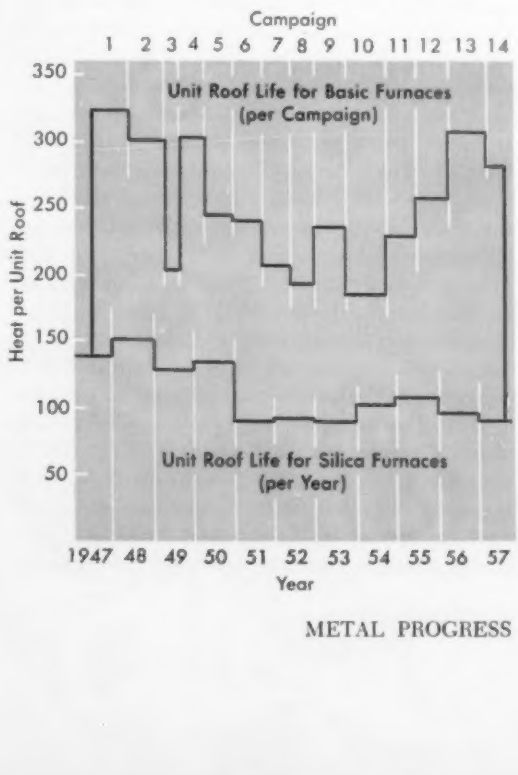
Republic Steel Corp. began investigating the all-basic openhearth late in 1956; while not having the extensive experience of U.S. Steel Corp., Republic also found that roof life and production increased. This was reported by C. W. Cravens who gave a blow-by-blow description of the first campaign.

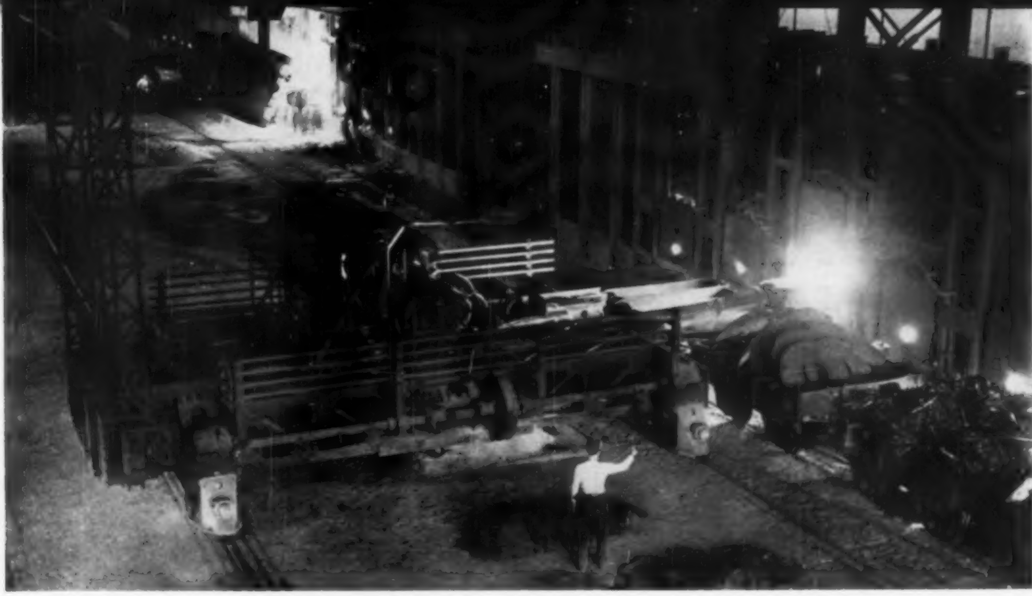
Initially, the roof was arch-constructed of cast basic refractory with simple jacks, consisting of two adjustable telescoping pipes, provided to control anticipated shifting of the roof. After the furnace was put into operation, daily checks of the roof were made. At the 16th heat, surface roughness appeared; it increased, though without visible wear, to the 104th heat when a light bulge appeared in the front roof section above No. 5 door. The jacks were adjusted to contain the bulging, but this did not work; bulging continued until several bricks dropped into the 209th heat during the working period.

Repair and relighting were completed without incident. It developed, as the campaign went on, that the patching material did not last as well as the original cast refractory, and several subsequent repairs were needed. These occurred after heats 313, 402 and 487. After 550 heats, the furnace was taken out of production and rebuilt using cast basic refractory exclusively for the roof, front wall and back wall. Since production results had revealed the advantages of basic roofs, another furnace was rebuilt in this manner. New jack models (94 in number), equipped with coil springs capable of exerting 1000 psi. when compressed, were installed in this furnace to maintain the roof contour along with 24 of the conventional telescoping jacks at the port ends. The contour and wear of this roof were both exceptionally good up to 225 heats; however, at this point, the cooling water pressure fell to 12 lb. due to weather conditions, and the furnace deteriorated. At 235 heats, it was rebuilt.

Discounting unfortunate incidents of this sort, Republic's experience indicated that their major problems resulted from variability in refractories and shortcomings of furnace design. Openhearths in present day use have all been built with silica roofs in mind; the different characteristics of basic brick require compensating adaptions. One important physical property is coefficient of expansion. While this can be calculated (in fact, it is given in a number of tables), the large number of variables in a major production unit such as an openhearth furnace make this procedure impossible. All the mason can

Fig. 2 — Unit Roof Life of All-Basic Furnace and Silica-Roofed Furnaces (South Works, U.S. Steel Corp.). In most cases the basic roof lasts from two to three times as long as the silica roof





do is use the old familiar "try-it-and-see" method. The results of such experimental work were discussed by L. L. Wells of U.S. Steel Corp. in his paper on "Expansion Allowance of Basic Port Ends".

All large refractory structures need allowances for expansion on heating. With too little allowances, distortion or rupture of the binding members can occur. Spalling, crumbling of the ends, and even severe buckling (such as occurred in the basic roof of Republic's furnace) have been known to happen. Conversely, too much allowance results in a loosely built furnace. Chinks permit the entrance of air and escape of flames which may in turn destroy supporting steel and refractory. The builder is thus restricted to narrow limits if he is to erect a sharply operating furnace with a long economical life.

Builders are, of course, fairly familiar with expansion allowances needed for silica brick construction. When basic brick is substituted, however, the allowances change, and have to be redetermined. The problem is compounded by the relative fragility of basic brick. For example, the premature failure of early uptake installations could have been caused by poor refractories, improper bricklaying, or faulty design of the supporting structure.

First efforts were toward altering brick types (using fired instead of chemically bonded brick, for instance), since early work indicated that the expansion allowance of 2.2% – one joint every six bricks – was more than adequate. Failures continued, and when the supporting steel work was examined, crushed bricks and broken castings were found. As a result, the allowance was increased to one corrugated expansion plate every fourth brick, or 4.4%.

Furthermore, all hangers from which brick were suspended were separated from building structure members to eliminate vibrational effects. As of now, pinch spalling still occurs in some areas, indicating that the optimum expansion allowance has not been reached, though results so far are encouraging.

British Experiences

Among the other papers submitted was a review of the all-basic openhearth in Great Britain. Early experiences were disappointing, the paper by J. McKenzie of United Steel Co. Ltd. stated. Interest slackened, only to be renewed by subsequent American developments. At present, the general feeling is that basic roofs will really prove themselves only when they are accompanied by other high-speed facilities, such as arrangements for faster charging and firing rates.

Evaluation

To sum up progress reports presented at the meeting, it is generally conceded that the all-basic openhearth melts steel more rapidly than a similar silica-roofed furnace. The basic roof lasts up to three times as long but the cost of basic brick is about triple that of silica. In the long run this increased roof life may prove to be the most important single feature. Repair costs are lowered and the furnace availability is greatly increased. Attention by the mason gang is appreciably lessened. With labor costs being such a significant item in today's production, the further development of the all-basic openhearth is assured.

Can an Improved Nonaging Steel Be Produced Commercially?

By ERIC R. MORGAN*

The successful development of an improved nonaging steel to replace aluminum-killed steel awaits the careful coordination of chemical composition, precise annealing and a special temper rolling technique. (N7, F23r, J23; CN-g)

As is well known to all makers and users of deep drawing sheet, tin plate and galvanized steels for formed parts, the sheet has an annoying habit of aging – that is to say, changing its properties during storage. This is ordinarily true of low-carbon steel which has been given a final cold pass – "temper rolled". Such a steel may very often be drawn into a difficult part if formed immediately, but after shipment and storage for some days, the same steel used in the same dies may show various surface markings, flutes or kinks, or even break. The surface irregularities ("stretcher strains" or "worms") are particularly objectionable if they occur in an exposed part to be painted or enameled. The surface markings (Fig. 1) represent depressions on stretched surfaces and infest regions where the maximum plastic strain is around 5%; they disappear in more heavily stretched regions.

If low-carbon steel sheet is rolled from aluminum-killed ingots, it may be nonaging, but the semifinished product may possess a surface which is inferior to that of rimmed steel. Alloying with boron or vanadium in unkilled steels can result in nonaging steels, but this expedient has not been consistently successful. However, as will be seen later, alloying plus new annealing and temper rolling routines offers considerable promise.

First it should be mentioned that two distinct aging phenomena are involved: *(a)* quench aging, which occurs in steels cooled rapidly from elevated temperatures, and *(b)* strain aging which occurs only in plastically strained steel.

Quench Aging

Quench aging is the result of precipitation of compounds from supersaturated solid solution. Carbon and nitrogen are the main culprits in low-carbon steel although small contributions can arise from other elements. Solubility of both carbon and nitrogen in ferrite is markedly affected by temperature; carbon solubility varies from 0.02% at 723° C. (1333° F.) to less than 10^{-7}% at room temperature, and nitrogen solubility changes from 0.10% at 585° C. (1085° F.) to approximately 2×10^{-5}% at 20° C. (68° F).

When carbides and nitrides are precipitated there is an increase in hardness, but this increase in hardness is not significant unless the total supersaturation giving rise to precipitation amounts to about 0.01% carbon plus nitrogen. In heat treated steel the degree of supersaturation will depend upon the amount of precipitation during cooling. The rate of precipitation of carbides and nitrides depends more on nucleation than on diffusion because both carbon and nitrogen diffuse rapidly in ferrite. The ease of nucleation can be affected by the pres-

*Assistant Director of Research, Jones & Laughlin Steel Corp., Pittsburgh. This article is a slightly abridged version of a paper presented late in October 1957, at Case Institute of Technology, Cleveland, before a Symposium on Annealing of Low-Carbon Steel, sponsored by Lee Wilson Engineering Co.

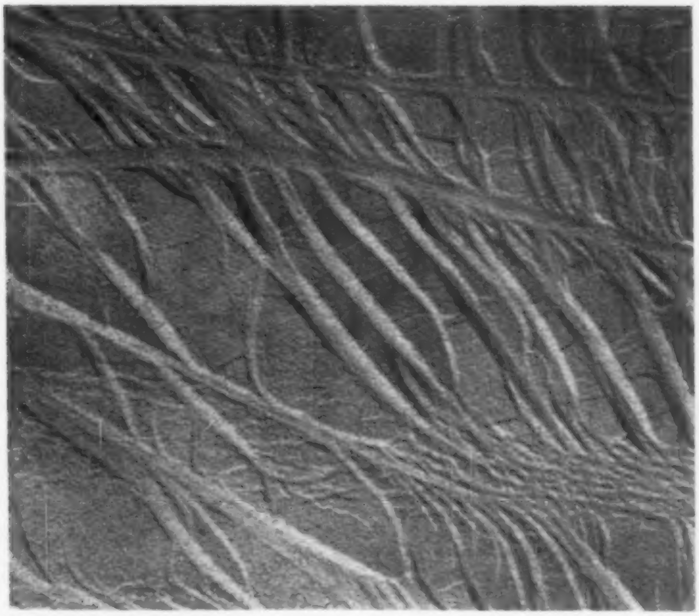


Fig. 1 — Stretcher Strains in a Sheet Steel Stamping ⅔ Actual Size

ence of existing precipitate particles and also by simultaneous precipitation of other compounds. For example, Wert [1] has shown that the rate of precipitation of carbon at 110° C. from a ternary iron-carbon-nitrogen alloy is more rapid than the precipitation of carbon in an iron-carbon alloy where no nitride is precipitating. The probable explanation of this phenomenon is that carbon is soluble in the precipitating nitride $Fe_{16}N_2$.

Consider then what happens during slow cooling in the box annealing of an openhearth rimmed steel which contains 0.06% carbon and 0.004% nitrogen. The major part of the carbon which was in solution at 723° C. (1333° F.) will be precipitated as Fe_3C by 260° C. (500° F.), but the more soluble nitrogen will not have started to precipitate, nor, with further slow cooling, would such action be promoted by the precipitating carbon because the carbide being formed will be Fe_3C in which nitrogen is not soluble. Considerable supersaturation of nitrogen occurs; as much as 0.002% nitrogen is left in solution at room temperature. If the precipitating carbide could be made to dissolve nitrogen, more nitrogen might be removed from solution with a normal heat treatment. The significance of this possibility is illustrated later in connection with strain aging.

Since, as remarked above, nucleation is a prime factor in quench hardening, it should be mentioned that anything which produces localized elastic strain (such as inclusions or cold work) also promotes nucleation. Even the presence of undissolved carbides will speed further precipitation of carbon.

When to these complications in nucleation and growth of precipitates are added variations in annealing temperature and cooling cycles, one

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2. "Elimination of Stretcher Strains in Mild Steel Pressings", by B. B. Hundy, *Journal*, Iron and Steel Institute, Vol. 178, 1954, p. 127.

3. "Rimmed, Nonaging, Vanadium-Treated Sheet Steel", by J. W. Frame and F. B. Schunk, A.I.M.E. Regional Symposium, Detroit, 1957.

4. "Effect of Quench Aging on Strain Aging in Iron", by A. H. Cottrell and G. M. Leak, *Journal*, Iron and Steel Institute, Vol. 172, 1952, p. 301.

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cannot forecast the quench aging behavior of low-carbon steels in commercial operations. If the mechanical properties alone are important, quench aging of box annealed low-carbon steels is insignificant. However, when the cooling rate is increased, as in normalizing or quenching, this comfortable situation changes.

Whatever the cooling rate from the annealing temperature, a low-carbon steel can be expected to have a heterogeneous stage at the beginning of plastic flow, as shown by the possession of an "upper" and a "lower" yield point. This discontinuity in the plastic flow of low-carbon steel sheet can be of much more importance to its "drawability" than the changes in hardness already discussed – although the two phenomena seem to be interrelated at the atomic level, as will be shown.

Figure 2 shows a typical stress-elongation curve for annealed low-carbon steel. Conventional gages show that the steel acts in an elastic manner up to the upper yield. At that point, localized plastic flow begins at stress concentrations and spreads through the entire cross section to form a Lüders' band or stretcher strain. With increasing strain the band grows – but at the lower stress level shown as the lower yield point. As the strain is increased, the Lüders' band may spread, or other bands may form, until the entire gage section is covered. The amount of strain is then referred to as the "yield elongation", and amounts usually to about 6% in annealed low-carbon steel.

If a further sample of such a steel is elongated about 2%, stretcher strains will appear; if elongated more than 6%, they cover the whole sheet and disappear. This phenomenon can be particularly important in a shallow drawing operation, as in the pressing of automobile door panels, where a rough surface must be avoided.

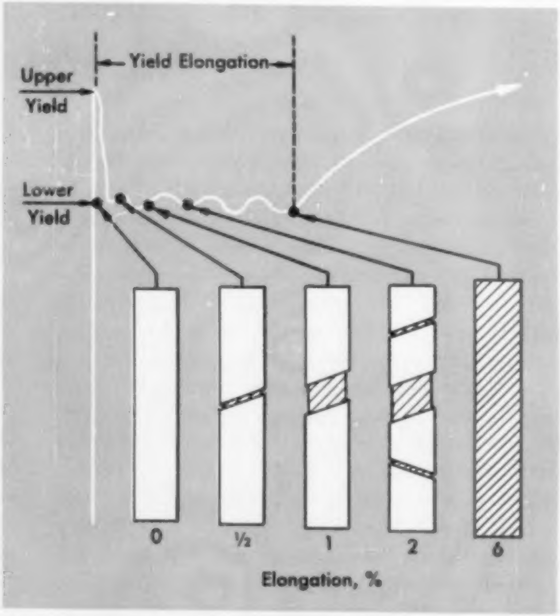


Fig. 2 – Typical Stress-Elongation Curve for Annealed Low-Carbon Steel Showing Relationship Between Total Strain and Formation of Lüders' Bands

Strain Aging

If a sample is loaded beyond the upper yield but strained less than the total yield elongation as to point X in Fig. 3, and then unloaded, it will, upon immediate reloading, continue to deform at a stress equal to the lower yield point until it reaches point Y. However, if there is a considerable delay between unloading and reloading, the sample may require a load greater than the lower yield point for plastic deformation to start. Similarly, if a sample is strained beyond the total yield elongation – say 8% – then unloaded and immediately reloaded, it will not show discontinuous yielding but it will deform as in diagram B. On the other hand, if the time of reloading is delayed, the yield point may return with a greatly increased yield stress (diagram D in Fig. 3). This return of the yield point is known as "strain aging".

Yielding and strain aging on an atomic scale are explained by the interaction of dislocations and interstitial atoms (C and N) in the alpha-iron lattice which seek places where the spacing between the iron atoms is increased. One such site is a dislocation, and carbon or nitrogen atoms can become firmly bound along dislocations. Once the migrating carbon and nitrogen atoms have come to rest at the dislocation sites, it becomes more difficult to move the dislocations than if they were free from these "atmospheres". This means that plastic deformation, which results from the movement and multiplication of dislocations, is more difficult when dislocations are pinned by carbon and nitrogen atoms.

When stress is applied to an annealed low-carbon steel, there will be, to a first approximation, no plastic deformation until the applied stress is sufficient to tear some dislocations away from their atmospheres and to continue to move them across the entire sample. This stress level corresponds to the upper yield stress. Once a sufficient number of dislocations are freed, plastic deformation can continue at a lower stress, the lower yield stress.

On an atomic scale, the reappearance of the yield point in diagram D, Fig. 3, at an elevated stress can be accounted for by the migration of interstitial atoms to the dislocations freed by the initial plastic prestrain; these dislocations are again pinned and need a higher stress before they can be moved again. Prolonged strain aging may actually result in a preferential nucleation of carbide and nitride precipitates at dislocations. This should strongly pin the dislocations and cause a readily observable yield point and decrease the ductility, as illustrated in Curve D of Fig. 3.

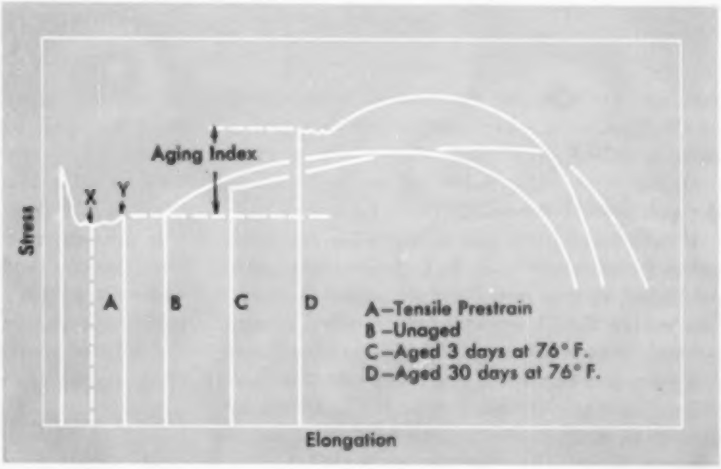


Fig. 3 – Typical Stress-Elongation Curve for Annealed Low-Carbon Steel and for Same After Tensile Prestrain and Strain Aging

Control of Strain Aging

Because strain aging is due to localized grouping of carbon and nitrogen atoms at dislocations, very small amounts produce a large effect. It can be shown that serious strain aging may result when only $10^{-4}\%$ carbon plus nitrogen is in solution and free to diffuse. Since the total supersaturation of these elements in box annealed low-carbon rimmed steel is normally greater than $10^{-4}\%$, strain aging can be expected.

The above considerations show that aging of low-carbon steel, tin plate and galvanized sheet used for deep drawing is a matter which is difficult to control within such limits as will cause no problems in production. In the past this control has either been unreliable or has cost so much money as to raise the cost of the finished article quite appreciably. Let us consider whether any more satisfactory control is in fact possible, having in mind the explanation of the complex phenomenon on the atomistic level.

The diffusivities and amounts of carbon and nitrogen in solution in low-carbon rimmed steel are high enough that significant strain aging occurs in a few hours at room temperature. Aging time cannot always be controlled by the consumer because deep drawing steels are temper rolled (strained) before shipping, and time in storage is determined by economic factors related to inventories. Diffusivity of carbon and nitrogen cannot be retarded by refrigeration because it would cost too much. By far the most simple and effective remedy is through control of the amounts of supersaturated carbon and nitrogen in the ferrite by eliminating these elements, fixing them in stable compounds through alloying, or by controlling the precipitation mechanisms and rates.

Removing carbon and nitrogen by heating in wet hydrogen is effective but uneconomical. Carbon and nitrogen may be removed from solution by alloying, but the addition of the necessary strong carbide-forming and nitride-forming elements usually imposes penalties in steel-

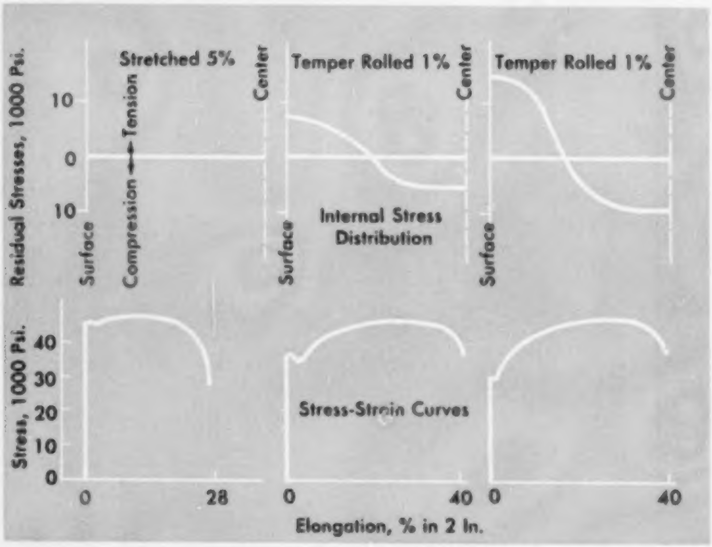


Fig. 4 – Relationship Between Magnitude of Internal Stress and Yield Point Phenomena in Temper Rolled Rimmed Low-Carbon Steel, Aged 60 Days at 76° F.

making. For example, the addition of aluminum or titanium, which are also strong deoxidizers, leads to killed steels with relatively poor yield from the ingot and inferior surface, hence raises the unit cost of the product.

If sufficient carbon and nitrogen can be eliminated from solution so that strain aging after prolonged storage is only of the order shown in Curve C of Fig. 3, we may have reached a commercial answer because the yield point will not reappear and there will not be any loss in ductility. To reach this goal, it would be necessary merely to restrict the carbon and nitrogen in solution, not to eliminate them completely.

Theoretically, this should be possible simply by very slow cooling, since the equilibrium solubility of carbon and nitrogen at room temperature is considerably less than 10^{-4}%. In practice, however, box annealing of high purity iron-carbon alloys will not precipitate sufficient carbon. On the other hand, the presence of trace amounts of impurities such as chromium promotes precipitation of carbon, so that in normal box annealed low-carbon steel, carbon makes only an insignificant contribution to strain aging. Supersaturation of nitrogen is the serious offender in such sheet because, as pointed out earlier, as much as 0.002% nitrogen can remain in solution after box annealing.

Precipitation of nitrogen can be facilitated by alloying with vanadium or boron, neither of which is a strong deoxidizer, but effective use of these additions requires the careful control of steelmaking practice. While neither element has been used regularly with complete success up to the present, there are already sufficient data to show that both addition elements offer considerable promise for the future.

If the amount of carbon and nitrogen in solution can be sufficiently restricted, the steel, while showing a return of the yield point during prolonged storage, should not suffer any loss of ductility or increase in tensile strength due to strain aging.

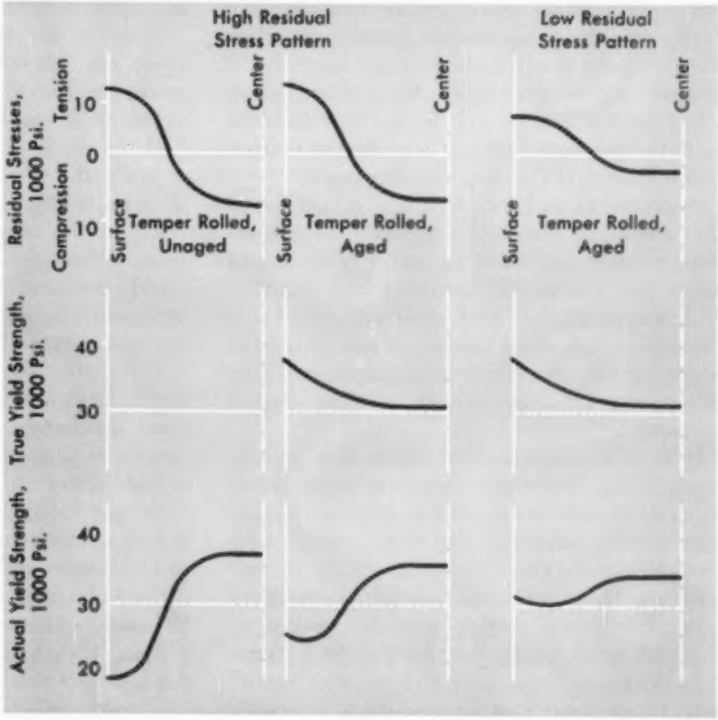
Yield Point Elimination

To eliminate the yield elongation in low-carbon steel it is necessary to remove virtually all the carbon and nitrogen from solution. It is reduced in extent by large grain size. The yield point can be eliminated by testing immediately after plastic deformation but, as pointed out earlier, it returns with time.

One of the testing conditions which appears to minimize the yield point is to bend the sample during the tensile test. This sets up a stress system which will initiate plastic flow, but will not immediately permit deformation to pass through the entire cross section of the sample, and thus prevents formation of Lüders' bands. The metal does, of course, possess a yield point, but this is masked by the applied stress system which dictates the deformation pattern.

A complex stress system of this type cannot readily be simulated in every pressing operation where the yield point is undesirable. The alter-

Fig. 5 – Relationship Between Residual Stresses Induced by Cold Work (Top Diagram), the True Yield Strength of the Metal Resulting From Cold Work and Aging (Middle Diagram), and the Resulting Flow Stress (Actual Yield) of the Metal as Shown in the Bottom Diagrams



native is to set up such a complex stress situation within the sample itself. What are the possibilities?

Stretching, as in a stretcher leveler, will leave only elastic microstresses within the sample and, apparently, these are not very effective in masking the yield point. Roller leveling will introduce both microstresses and macrostresses, but because the latter are not very large, masking of the yield point is short lived. In contrast, temper rolling can introduce elastic macrostresses of considerable magnitude[2] and can, therefore, be very effective in masking the yield point, as shown by the fact that some temper rolled rimmed steels do not acquire a yield point for several months. Unfortunately, temper rolling is not always effective unless it is associated with large residual elastic stresses. This is indicated by the right-hand diagrams in Fig. 4.

It might be postulated that those conditions which induce high residual stresses during temper rolling will also be most effective in masking the yield point in strain-aged steel, but it is important to realize that aging is not prevented or even retarded by residual stresses. This has been verified by holding tensile prestrained samples under homogeneous elastic stresses for a month or so. When the stress is removed, the effects of aging are immediately observable in a tension test. Again, if the steel shown in the right-hand diagram of Fig. 4 is stretched 5%, the internal stresses are ironed out and the stress-strain diagram of the freshly strained steel shows no upper and lower yield. On the other hand, if the latter is aged 30 days at room temperature, the yield point reappears.

The effectiveness of temper rolling is not the same in all directions, differences being noted between the transverse and rolling directions. It can be said generally that the effectiveness of temper rolling will increase with *(a)* greater reduction, *(b)* rougher roll surfaces, *(c)* larger grain size, and *(d)* smaller roll diameters. If, however, strain aging does occur, it will be more serious the greater the amount of reduction. For example, although 5% reduction may be more effective than 1% in masking the yield point for a given aging time, it will usually also reduce the ductility of the aged steel to a greater extent.

Future Developments

Although a great deal of fine research has been extended on the quench aging of relatively pure iron alloys, there is little accurate information

about normal steels and irons. Even though it has been established that regular box annealing cycles are satisfactory for precipitation of carbon in normal steels, it is common knowledge that it is generally unsatisfactory for rimmed steels which contain nitrogen. It is time that we begin to tailor our annealing cycles to fit the precipitation kinetics of the deep drawing steels.

Recent work by Frame and Schunk[3] has shown that annealing time and temperature for vanadium-treated steel must be narrowly controlled to produce a successful nonaging steel. Similarly, it was established by Cottrell and Leak[4] that suitable quench aging treatments can be used to remove sufficient carbon from solution in iron to render it innocuous insofar as strain aging is concerned.

It is most important to realize that rapidly precipitating phases can accelerate precipitation of elements which are soluble in these phases. This is well illustrated by Wert's work[1] with Fe-C-N alloys. One of the drawbacks of that system is that Fe_3C, which is the predominant precipitate during cooling from box annealing, does not have any solubility for nitrogen. However, Nicholson[5] and also Morgan and Shyne[6] have pointed out that boron, which is readily soluble in Fe_3C, may promote the solubility of nitrogen in that carbide. Perhaps here is the basis for entirely new annealing cycles to produce higher quality deep drawing steels which do not exhibit strain aging – namely, controlled precipitation through alloying.

Another signpost directing the metallurgist to a solution of the aging problem is the fact that, under certain conditions, the return of the yield point due to strain aging can be masked by residual stresses introduced during temper rolling. Residual elastic tensile stress exceeding 10,000 psi. may be enough. To understand the significance of this statement, remember that the maximum observed increase in flow stress due to strain aging of low-carbon rimmed steel is about 9000 psi.

Since temper rolling is a heterogeneous deformation process, it is not surprising to find a considerable variation in the degree of effectiveness of the various cold rolling procedures. If the temper rolling pass is light, the surface regions are deformed, whereas certain of the center regions remain largely undeformed. Such a material, if immediately pressed into a part, would not show stretcher strains, because the dislocations in the deformed regions would be free. If this temper rolled sheet were stored and allowed to age, the yield point might return in the deformed regions.

Whether this will happen or not will depend upon the relative magnitudes of the residual stresses and on the increase in yield stress which occurs with time during aging.*

If the residual tensile stress at the surface is only about 5000 psi., as shown by the right-hand diagram of Fig. 5, its benefit could soon be canceled by the increasing yield stress at the surface. When the flow stress becomes approximately the same throughout the sheet, the yield point can be observed again and stretcher strains can occur in a drawn part.

If this simple explanation is correct, it is logical to conclude that, in order to mask the yield point indefinitely, the residual stresses must be greater in magnitude than the potential increase in yield stress.

Temper rolling will introduce residual stresses of varying magnitude depending upon conditions in the temper mill, such as roll roughness, but it should be possible to introduce a certain specified minimum residual stress. If this minimum is greater than the potential increase in yield stress due to strain aging, then the material will be "nonaging" in service. In other words a combination of controlled temper rolling with steels of restricted aging capacity may result in "nonaging" steels. At the same time, the fact that the degree of strain aging has been restricted by the alloying and annealing practice will elminate the other deleterious effects of aging – namely, increased hardness and reduced ductility.

If this hypothesis can be substantiated, then the prospects of producing improved nonaging steels treated with boron or vanadium are greatly enhanced.

*The top row of diagrams in Fig. 5 shows the pattern of internal stress, surface to center, in temper rolled sheet. Immediately after heavy temper rolling (left-hand diagram), the metal itself is fairly homogeneous, surface to center, has a yield of 30,000 psi., and in no part would exhibit the upper and lower yield phenomenon. Obviously, however, since its surface layers are under about 12,500 psi. tensile stress (residual), a piece of metal in a tension test or a forming die would start to yield at the surface when an externally imposed stress of 17,500 psi. had been reached (as shown in the lower diagram at left). The center set of diagrams shows how aging changes the pattern; the residual stress (shown at top) is unchanged with time, but the true yield increases in those portions which have been strained so the actual flow stress (shown at bottom) creeps up more at the surface than at the center which was not homogeneously deformed during the temper rolling process.

Staff Report

Multilayer Nickel Coatings

Duplex and multiplex systems for nickel plating hold promise of giving bright plated work with better corrosion resistance. (L17; *Ni*)

In 1947, Subcommittee II of A.S.T.M. Committee B-8 on Electrodeposited Metallic Coatings initiated a program of atmospheric exposure tests which had as its primary objective a study of the relative durability of decorative copper-nickel-chromium versus nickel-chromium coatings on steel of bumper bar grade. Among the panels exposed in the marine atmosphere at Kure Beach, S.C., were sets prepared with two layers of nickel. The first coating of Watts nickel was buffed and then a second identical coating was applied. Exposure tests for a period of three years of samples with a total coating thickness of 0.001 in. and 0.0015 in. demonstrated that the corrosion protection of this nickel-buff-nickel coating was appreciably better than the equivalent thickness of a single nickel plate or a copper-nickel coating.

These observations have resulted in modified plating techniques which promise to give commercial bright nickel-chromium electroplates of improved corrosion resistance. This point was brought out by Myron B. Diggin, vice-president and technical director, Hanson-Van Winkle-Munning Co., Matawan, N.J., in speaking at a Symposium on Nickel Plating held recently by the Cleveland Branch, American Electroplaters' Society. Today's counterpart of these double layer deposits, according to Mr. Diggin, usually employs a duplex system using a semibright undercoating of leveling nickel, usually up to 80% of the total thickness required, and 20% of the full-bright leveling nickel deposit as the top coating. A photomicrograph showing the construction of this type of coating is shown in Fig. 1. It is possible to change the character of the

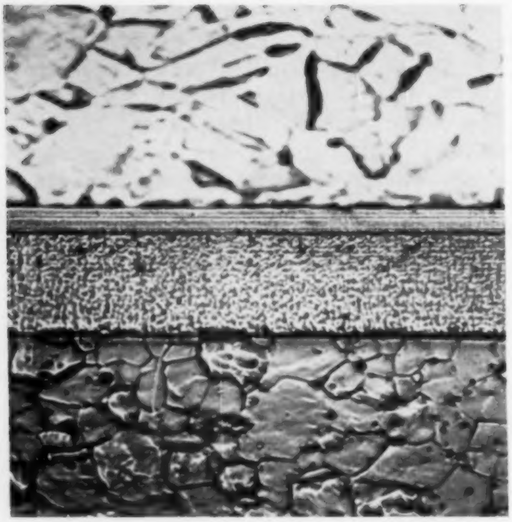


Fig. 1 – Photomicrograph of 0.001-In. Nickel Plate on Bumper Bar Consisting of 0.0008 In. of Semibright Nickel Followed by 0.0002 In of Full-Bright Plate. 750 ×

deposit by changing plating conditions, such as agitation, for example.

Duplex coatings are being used on steel automotive parts, such as bumper bars and grills, and give improved corrosion resistance over straight nickel deposits of equivalent thickness. Recently, duplex nickel deposits have been applied to copper-plated zinc die castings with increased corrosion protection reported up to 30% compared with equivalent copper and nickel thicknesses.

Mechanism of Corrosion

Mr. Diggin presented evidence to show that in duplex coatings exposed on atmospheric corrosion racks, initial corrosion starts in the top coating which has a typical laminar structure. Small pores are formed which after several months penetrate to the semibright nickel undercoating which has more of a columnar structure. Then instead of corrosion proceeding through the undercoating to the base at a normal rate, the pores in the top coating become wider. In other words, corrosion proceeds laterally instead of downward until appreciable areas of the top coating have been corroded away. The top photomicrograph in Fig. 2 illustrates initial corrosion of the bright top layer. The lower micro, made after atmospheric testing for over a year, shows the undercoating exposed and indicates that corrosion is proceeding laterally. It appears that potential differences in the two coatings lead to sacrificial action by the top coat in protecting the nickel layer underneath.

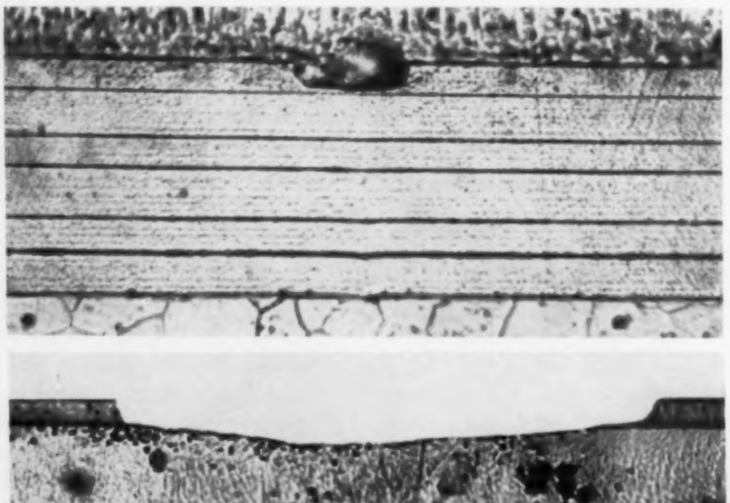


Fig. 2 – (Top) Corrosion has Started on the Outside Bright Coating of This Multilayer Nickel Plate. (Bottom) After exposure of over a year, corrosion appears to be proceeding laterally through the outside coating rather than penetrating the coating thickness to expose base metal. (1000×)

12-ton cast Nickel steel die produced by the Detroit Gray Iron Foundry Company, Detroit, Michigan. Die has sections up to 2 feet thick.

Forms floor pans of "production-line" Fords...

Big runs don't faze deep-hardened cast Nickel steel die

This cast Nickel steel die cold-forms heavy-gauge carbon steel sheets into floor pans for production-line Fords.

This is grueling service: production runs of well over a million pieces . . . severe abrasion . . . terrific impact.

For this reason, Ford uses a deep-hardening nickel alloy steel. Nominal composition is 0.50 per cent Carbon . . . 0.60 - 0.75 per cent Chromium . . . 1.50 - 1.75 per cent Nickel.

Nickel steels are just right for many applications

For parts with massive sections, or variable sections, nickel alloyed steels offer high strength, hardness, toughness and wear resistance. Alloying with Nickel also permits satisfactory heat treatment to develop the full properties of the materials.

A Nickel alloy steel—cast or wrought — may be the answer for your special service or fabrication need. If you'd like an Inco specialist to work along with you in selecting the right grade, just write. Include details.

The INTERNATIONAL NICKEL COMPANY, Inc.
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INCO NICKEL

NICKEL ALLOYS PERFORM BETTER LONGER

Standard Stainless Steels, Wrought and Cast

Wrought Stainless Steels *(a)*

(American Iron and Steel Institute Designations; June, 1957)

Type No.	Carbon	Chromium	Nickel	Other Elements *(b)*
201	0.15 max.	16.0-18.0	3.5- 5.5	Mn 5.5-7.5; N 0.25 max.
202	0.15 max.	17.0-19.0	4.0- 6.0	Mn 7.5-10.0; N 0.25 max.
301	0.15 max.	16.0-18.0	6.0- 8.0	
302	0.15 max.	17.0-19.0	8.0-10.0	
302 B	0.15 max.	17.0-19.0	8.0-10.0	Si 2.00-3.00
303	0.15 max.	17.0-19.0	8.0-10.0	Mo and Zr 0.60 max.
303 Se	0.15 max.	17.0-19.0	8.0-10.0	Se 0.15 min.
304	0.08 max.	18.0-20.0	8.0-12.0	
304 L	0.03 max.	18.0-20.0	8.0-12.0	
305	0.12 max.	17.0-19.0	10.0-13.0	
308	0.08 max.	19.0-21.0	10.0-12.0	
309	0.20 max.	22.0-24.0	12.0-15.0	
309 S	0.08 max.	22.0-24.0	12.0-15.0	
310	0.25 max.	24.0-26.0	19.0-22.0	Si 1.50 max.
310 S	0.08 max.	24.0-26.0	19.0-22.0	Si 1.50 max.
314	0.25 max.	23.0-26.0	19.0-22.0	Si 1.50-3.00
316	0.08 max.	16.0-18.0	10.0-14.0	Mo 2.00-3.00
316 L	0.03 max.	16.0-18.0	10.0-14.0	Mo 2.00-3.00
317	0.08 max.	18.0-20.0	11.0-15.0	Mo 3.00-4.00
D 319	0.07 max.	17.5-19.5	11.0-15.0	Mo 2.25-3.00
321	0.08 max.	17.0-19.0	9.0-12.0	Ti is 5×C (min.)
347	0.08 max.	17.0-19.0	9.0-13.0	Cb-Ta 10×C (min.)
348	0.08 max.	17.0-19.0	9.0-13.0	Cb-Ta 10×C (min.); Ta 0.10 max.
403	0.15 max.	11.5-13.0		Si 0.50 max.
405	0.08 max.	11.5-14.5		Al 0.10-0.30
410	0.15 max.	11.5-13.5		
414	0.15 max.	11.5-13.5	1.25-2.50	
416	0.15 max.	12.0-14.0		Same as Type 303
416 Se	0.15 max.	12.0-14.0		Se 0.15 min.
420	0.15 min.	12.0-14.0		
430	0.12 max.	14.0-18.0		
430 F	0.12 max.	14.0-18.0		Same as Type 303
430 F Se	0.12 max.	14.0-18.0		Se 0.15 min.
431	0.20 max.	15.0-17.0	1.25-2.50	
440 A	0.60-0.75	16.0-18.0		Mo 0.75 max.
440 B	0.75-0.95	16.0-18.0		Mo 0.75 max.
440 C	0.95-1.20	16.0-18.0		Mo 0.75 max.
446	0.20 max.	23.0-27.0		N 0.25 max.
501	Over 0.10	4.0- 6.0		Mo 0.40-0.65
502	0.10 max.	4.0- 6.0		Mo 0.40-0.65

Notes on Wrought Steels

(a) All composition ranges are based on ladle analysis. Standard permissible variations from specified chemical ranges or limits for check analysis are shown in Section 24, Steel Products Manual.

(b) **Manganese:** 2.00 max. in all 300 types; 1.00 max. in all 400 and 500 types except 416 and 416 Se (1.25 max.), 430 F and 430 F Se (1.25 max.) and 446 (1.50 max.).

Silicon: 1.00 max. in all types except as noted in the column "Other Elements".

Phosphorus is 0.060 max. in 201 and 202, 0.045 max. in all the 300 and 400 series except 0.20 max. in 303 and 303 Se, and 0.040 max. in all other types except 416, 416 Se, 430 F and 430 F Se (0.06 max.).

Sulpur is 0.030 max. in all types except 303, 416, 430 F, in each of which it is 0.15% min., and 0.06 max. in 303 Se, 416 Se and 430 F Se.

Molybdenum and **Zirconium** in 303, 416 and 430 F. are at producer's option and are reported only when intentionally added.

Cast Stainless Steels *(c)*

(Alloy Casting Institute Designations; 1956)

Type No. *(d)*	Carbon	Silicon (Max.)	Chromium	Nickel	Other Elements *(e)*
CA-15	0.15 max.	1.50	11.5-14.0	1.0 max.	*(g)*
CA-40	0.20-0.40	1.50	11.5-14.0	1.0 max.	*(g)*
CB-30	0.30 max.	1.00	18.0-22.0	2.0 max.	
CC-50	0.50 max.	1.00	26.0-30.0	4.0 max.	
CE-30	0.30 max.	2.00	26.0-30.0	8.0-11.0	
CF-4	0.04 max.	2.00	17.0-21.0	8.0-11.0	
CF-4 M	0.04 max.	1.50	17.0-21.0	9.0-13.0	Mo 2.0-3.0
CF-8	0.08 max.	2.00	18.0-21.0	8.0-11.0	
CF-8 C	0.08 max.	2.00	18.0-21.0	9.0-12.0	Cb or Cb+Ta; *(f)*
CF-8 M	0.08 max.	1.50	18.0-21.0	9.0-12.0	Mo 2.0-3.0
CF-12 M	0.12 max.	1.50	18.0-21.0	9.0-12.0	Mo 2.0-3.0
CF-16 F	0.16 max.	2.00	18.0-21.0	9.0-12.0	Mo 1.5 Max.; P 0.17 max.; Se 0.20-0.35
CF-16 Fa	0.16 max.	2.00	18.0-21.0	9.0-12.0	Mo 0.40-0.80; S 0.20-0.40
CF-20	0.20 max.	2.00	18.0-21.0	8.0-11.0	
CH-20	0.20 max.	2.00	22.0-26.0	12.0-15.0	
CK-20	0.20 max.	2.00	23.0-27.0	19.0-22.0	
CN-7M	0.07 max.	*(h)*	18.0-22.0	21.0-31.0	Mo; Cu *(h)*
HA	0.20 max.	1.00	8.0-10.0		Mo 0.9-1.20
HC	0.50 max.	2.00	26.0-30.0	4.0 max.	*(g)*
HD	0.50 max.	2.00	26.0-30.0	4.0- 7.0	*(g)*
HE	0.20-0.50	2.00	26.0-30.0	8.0-11.0	*(g)*
HF	0.20-0.40	2.00	19.0-23.0	9.0-12.0	*(g)*
HH	0.20-0.50	2.00	24.0-28.0	11.0-14.0	N 0.2 max.; *(i)*
HI	0.20-0.50	2.00	26.0-30.0	14.0-18.0	*(g)*
HK	0.20-0.60	2.00	24.0-28.0	18.0-22.0	*(g)*
HL	0.20-0.60	2.00	28.0-32.0	18.0-22.0	*(g)*
HN	0.20-0.50	2.00	19.0-23.0	23.0-27.0	*(g)*
HT	0.35-0.75	2.50	13.0-17.0	33.0-37.0	*(g)*
HU	0.35-0.75	2.50	17.0-21.0	37.0-41.0	*(g)*
HW	0.35-0.75	2.50	10.0-14.0	58.0-62.0	*(g)*
HX	0.35-0.75	2.50	15.0-19.0	64.0-68.0	*(g)*

Notes on Cast Steels

(c) Most of these are also covered by A.S.T.M. specifications A296-55 and A297-55.

(d) Designations with the initial letter C indicate alloys generally used to resist corrosive attack at temperatures less than 1200°F. Designations with the initial letter H indicate alloys generally used under conditions where the metal temperature is in excess of 1200°F.

(e) **Manganese:** 1.00 max. in CA-15, CA-40, CB-30 and CC-50; 1.50 max. in all other C alloys; 0.35-0.65 in HA; 1.00 max. in HC; 1.50 max. in HD; 2.00 max. in all other H alloys. **Phosphorus** and **Sulphur:** each 0.04 max. in all alloys except CF-16 F, wherein P is 0.17 max., and in CF-16 Fa, wherein S is 0.20-0.40.

(f) **Columbium** 8 × C min., 1.00% max.; Cb + Ta 10 × C min., 1.35 max.

(g) **Molybdenum** 0.5 max. (not intentionally added).

(h) Proprietary alloys contain varying amounts of Si, Mo and Cu.

Successful Southwestern Congress

Technical sessions at the ⊛'s first Southwestern Metal Exposition in Dallas, Texas, May 12 to 16, included 28 topics suggested by a local committee and fell within three areas – Metals for the Astronautic Age, Forming and Fabricating Difficult Alloys, and Corrosion in Chemical and Petroleum Industry. The Society for Nondestructive Testing also held eight sessions on Principles, Methods and Equipment. All-in-all, an excellent program, the complete proceedings to be published shortly in a separate volume.

FUTURE METALS – In the opinion of Clarence H. Lorig of Battelle Memorial Institute (and vice-president ⊛), we can not expect much more than we already have in alloys based on iron, nickel or cobalt. Our best chance lies in new alloys (bare or protected) of molybdenum, columbium, chromium, and possibly vanadium. Their potentialities now are only dimly known. Since strength at high temperature is roughly proportional to melting points, these metals should give strong alloys because they melt at 3400 (for chromium) to 4750° F. (for molybdenum). H. R. Ogden, also of Battelle, elaborated these thoughts, saying that the "space-age metals" must have a combination of properties difficult to achieve, such as oxidation resistance, high creep resistance at high temperature, be rolled into thin sheet, capable of being fabricated and joined into complex yet accurate shapes, and be reasonably available. Some of these "pure" metals have been produced in commercial quantities so recently that their capabilities have not yet been explored, but major obstacles must be overcome, such as catastrophic oxidation of molybdenum, and brittleness of chromium.

Protection of surfaces by ceramic coatings is a new yet very useful expedient, as indicated in a paper by Nathaniel Cannistraro of Bettinger Corp. Combustion chamber liners made of 78-10 Ni-Cr sheet when burned out are being replaced with coated 25-12 Ni-Cr alloy; when the engine starts, this is heated to 1600° F. in a few seconds; thermal stresses are correspondingly large. Another modern application is the narrow strips of aluminum oxide on the Explorer satellite. It has high reflectivity and keeps the instruments inside at normal temperature though in every 2-hr. circuit the outside varies from −150° F. in the shade to +600° F. in the sun.

The prime requirement of a coating is that it should slow down or prevent reaction between metal and the surrounding environment – usually oxidation. This means generally that the coating should be a refractory oxide, of which there are many. Preferably the whole part should be protected *after* fabrication. Cleaning is essential; frequently a nickel flash then follows. The coatings with binders are mixed into a thin slurry and a uniformly thin layer results from a simple dip. Then follows firing. Cannistraro said that protected truck exhaust pipes of plain steel would outlast the truck engines.

High-Quality, High-Strength Castings – A number of papers were read about metals for fast airplanes, principally by staff members of nearby Chance Vought Aircraft and Convair. Much of this was in addition to the information presented a year ago at the Western Metals Congress in Los Angeles and outlined in *Metal Progress* for May 1957.

John K. Dietz of Chance Vought said they were able to get high-quality castings by working closely with the foundrymen, recognizing that chemical analysis should "balance" rather than crowd the composition limits, and insisting on lowest pouring temperatures and proper

gating. Certain compromises are necessary in surface smoothness and dimensional tolerances; also the inevitable solidification defects must be located in harmless regions. The rewards are constructional units of great complexity, high strength and minimum cost.

Mr. Dietz said that deliveries of castings to modified 4340 analysis have consistently met the listed tensile properties. He holds AM 355 in high regard for its high tensile strength (180,000 psi.) at 1000° F., and said that the "toolsteel" alloy looks very promising. He estimates a potential annual market of $125,000,000 in this growing field.

High-Strength Forgings – Apparently most of these are used at ambient temperature (as in landing gear) or certainly no higher than 600° F. The ones now being used are, according to Seymour Goodman of Chance Vought Aircraft, 4340 or A.M.S. 6415, 4330 or A.M.S. 6427, Timken's HS-220 or A.M.S. 6407, and Crucible's Hy-Tuf or A.M.S. 6418.

J. J. Russ of Steel Improvement & Forge Co. pointed out that considerable variation exists, ingot to ingot, and heat to heat. This is especially true of the transverse properties desirable in many of the forgings, and is a weak spot in the otherwise desirable 4340 steel. He gave tables showing that the average elongation of ingots of many heats (billets tested transversely) was somewhere around 7%, but many tests were below the desired 4% min. Transverse properties and cleanliness are far better in vacuum cast ingots, as well as those made by consumable electrodes or by the Kellogg process*, but the small ingots now available limit the size of forging. Another point: Superalloys, useful at really high temperatures, forge with great difficulty – as might readily be predicted.

Paul Kikeli of Cleveland Pneumatic Tool Co. said that all forgings must be sufficiently oversize for a machining allowance equal to the minimum allowable distortion after heat treating plus the thickness of the inevitable decarburized skin. Since these parts are of complex shape and heat treated to C-52 or C-53, contour and profile machining is very costly in time and money, requires very rigid and strong fixtures, and frequent renewal of the carbide cutting tools. At times the machinist faces a dilemma – a necessary cutting speed may cause so much vibration and generate enough heat to prevent desired accuracy and surface hardness in the finished part.

*See *Metal Progress*, December 1954, p. 81.

Sandwich Fabrication – Honeycomb construction is a better name for composite panels with core made of corrugated narrow strips, on the order of 0.0015 in. thick, spot welded at the touching nodes. Overlaid on this is an outer skin, a sheet perhaps 0.008 in. thick, and an inner skin somewhat thinner. The problem is to make a good and uniform joint between skins, cores and edge members.

According to J. C. Herr of Convair, the prime essential is *cleanliness* not only in preparation of the parts but also in their joining. In panels made of the high-temperature magnesium and aluminum alloys, bonding is by an organic tape or sheet which is really a thermosetting plastic. Under pressure of 175 psi. and 350° F. the tape flows, bonds the details together, and holds secure at any operating temperature up to 300° F.

Panels of 17-7 PH, useful for much higher temperature, are brazed together in a properly shaped vacuum box (to give tight contact), purged of air and under partial pressure of argon. A silver-copper brazing alloy with lithium flux flows into the joints when the assembly is heated to 1675° F. It is then rapidly cooled to 1400° F. and held there for the first step in the precipitation hardening treatment, cooled to 70°, the panel removed from the container, refrigerated and aged.

While it is common practice to attach test tabs to all panels, it is another thing to be sure that *all* metal in contact in the finished part is strongly joined. An X-ray will show that the braze is in the right place, but tells nothing about adherence. Recently "flash" testing has been introduced, wherein a 4-in. area is heated to 800° F. in 2 sec. by quartz envelope heaters and is rapidly cooled. Any buckling at that area, either of inner or outer cover, indicates insufficient bonding strength. Mr. Herr believes that a fast ultrasonic device with automatic recording equipment will soon be available to inspectors.

Corrosion Problems

The two meetings devoted to corrosion in the petroleum and chemical industries emphasized two facts – there is no panacea, either base metal or protective coating and, second, the tremendous importance of seemingly trifling differences in metals and environment. Wayne Friend of International Nickel Co. listed several variants of the stainless steels and the nickel-copper alloys where 1 or 2% of a third or fourth element would fit the alloy for specific environ-

ments. He also said that titanium could solve many tough problems. Apparently much attention is now being turned to the corrosive action of sulphur compounds either in hot gases or in liquid solutions. Metallic sulphides, the product of reaction, are voluminous, flaky and fusible.

R. V. Comeaux of Humble Oil and Refining Co. favors ordinary carbon steel for refinery equipment handling solutions no hotter than 450° F. and containing moderate amounts of H_2S. Baytown refinery uses very little high alloy; sulphidation of the plain carbon steel tubes, pipe, valves and vessels is minimized by ingenious design (to avoid swirling fluids), careful operation (to prevent accidental temperature surges) and proper neutralizing with caustic and organic inhibitors (even diluting dangerous solutions with clear water).

Much attention was also given at these sessions to nonmetallic protective coatings – of which the number seems to be legion. On one thing all speakers were in agreement – the absolute necessity of *clean* metal before applying any coating. "Condition I" requires degreasing, neutralizing, pickling, washing, and then sandblasting to "white metal" – the last step also giving the roughened surface necessary for "tooth". Sand-blasting and final optical inspection of the inside of a long piece of 1 to 3-in. pipe is quite a trick – to say nothing of difficulties of insuring continuous coatings at a joint of any kind.

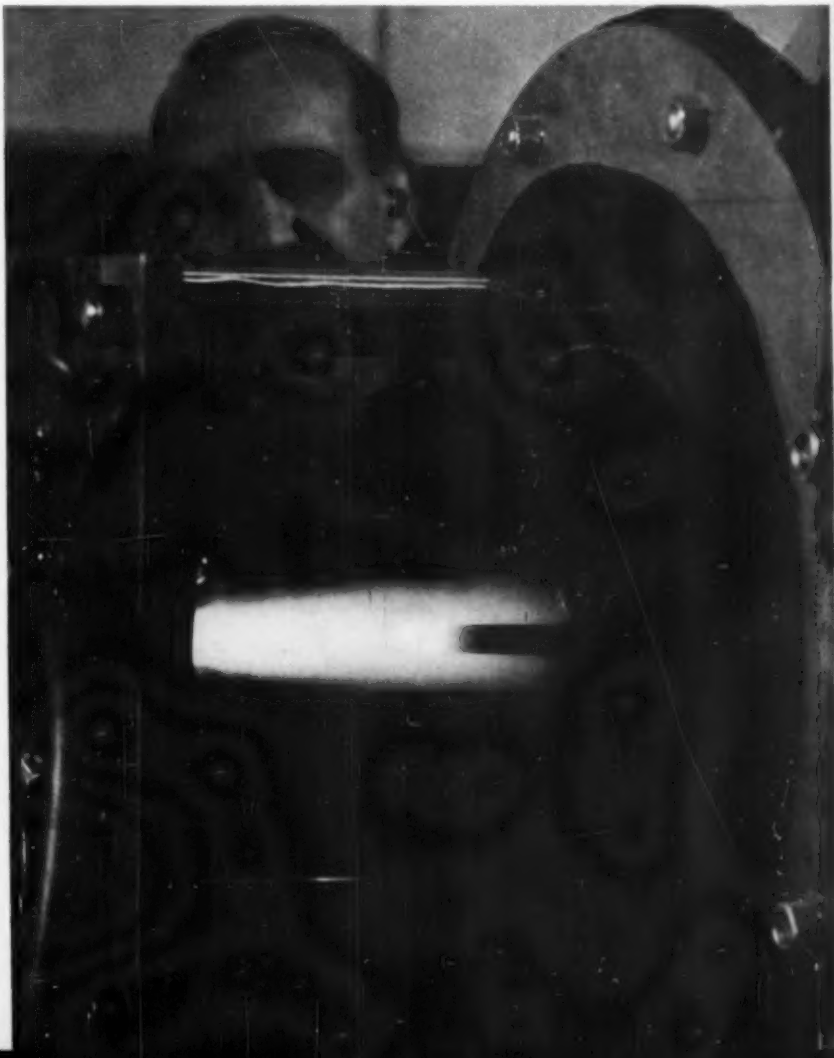
Good success was reported in protecting ordinary structural steel against sea water corrosion by zinc silicate, as described by Jack Eggleston of Vapor Honing Co. First the steel is sand-blasted, then a mixture of zinc powder and "liquid silicate" brushed or sprayed on in 1-mil. layer, a "curing agent" applied and protected 2 hr. from water. As many layers as thought necessary are layed on and cured, after which a wear resistant overcoat – presumably paint – is applied.

Selecting the Best Methods

Quality control in industry today uses all available methods of nondestructive testing; however, it's important to choose the best test method for the job. This was the theme of an educational survey of the Society for Nondestructive Testing as part of the technical meeting in Dallas.

In outlining the uses for radiography, W. D.

One of the interesting exhibits shown by the 247 firms at the First Southwestern Metal Exposition at Dallas was the "Plasmatron" made by the Giannini Plasmadyne Corp. of Santa Ana, Calif. It converts a flow of gas such as argon into a jet of plasma (free ions and electrons travelling at speeds corresponding to temperatures of from 8000 to 15,000° C.). With the help of magnetic forces similar to those used in equipment for studying the thermonuclear fusion of hydrogen, a sharp intense flow of energy is projected from a small nozzle. The illustration shows such a jet discharging into a chamber at low vacuum and heating the end of a graphite pencil – a test simulating conditions met by the nose cone of a transcontinental missile when it re-enters the atmosphere on its downward plunge.



Kiehle, Eastman Kodak Co., pointed out that the assurance of soundness which this test method gives can result in the use of smaller parts in critical applications. Also weld inspection can correct procedures to give optimum properties.

Radiographic inspection of castings may result in design changes to give a better part. Many castings are inspected before machining to avoid work on substandard parts. Radiography has shown how to locate risers to eliminate shrinkage and to improve casting procedure for crankshafts.

Fluoroscopy – W. R. Hampe, Westinghouse Electric Corp., Baltimore, Md., was emphatic: "Improvements in technique have increased uses for fluoroscopy in applications which have been limited to less desirable methods. It meets the requirements of modern production for an accurate, low-cost, nonrecording, high-volume means of internal inspection". A limiting factor is comparatively poor sensitivity, due to limitations of some of the components, but Mr. Hampe belives that radiography can be approached by adhering to the basic factors which produce the best fluoroscopic image.

Fluoroscopy is particularly successful in locating linear discontinuities. Because the inspector can move the part, he can receive an image from several directions. Shrinkage may be seen readily if it is of the cavity type or of the coarse sponge variety–even microshrinkage can be picked up by experienced operators. If the inclusion has a preferred geometry which is hard to register on an X-ray plate, then fluoroscopy may do the trick.

Penetrant Inspection – Here reliability of reproduction is essential; the result must be the same whether 100 or 10,000 parts are inspected –a point emphasized by John Harrer of Magnaflux Corp. as he described the more sensitive penetrants. Inspectors relying on penetrants are concerned with four main variables: (*a*) materials; (*b*) techniques; (*c*) processing methods used on the part which may affect the test; (*d*) types of discontinuities. Another important point is what to do about defects when they are found.

Sensitivity is a combination of many things, Mr. Harrer pointed out. Fluidity of the penetrant governs the ability of material to enter fine defects. Enough material must remain on the surface to feed penetrant constantly into the crack. Vibration of parts under test by ultrasonics is an improvement.

Eddy currents will reveal cracks, voids and fissures. In addition, the state of heat treatment, eccentricity of tubing, and thickness of coatings can be measured. Hamilton Migel of Magnaflux Corp. emphasized the importance of acceptance standards. A reference method has been worked out whereby the part itself is used as the standard. Called the "Percent Ring Standard," it uses eddy current instruments as important industrial inspection tools. Experiments showed that there is a very small percentage difference in the total signals produced by similar parts in eddy current instruments. Acceptance limits may then be defined as an accurately calibrated fraction of this signal, and it may be as small as 0.1% of an absolute value set for a pedigreed sample.

Ultrasonic Testing is being used by practically every industry manufacturing important parts, according to John Smack of Curtiss-Wright Corp. and P. K. Bloch of Branson Instruments, Inc.

Although the trend is toward automatic inspection, the quantity must be sufficient to justify the engineering and expense.

Mr. Bloch emphasized that the resonance method is capable of high accuracy. Its three principal fields of application are (*a*) dimensional gaging; (*b*) detection of laminar discontinuities and (*c*) testing for lack of bond. For example, the nose cone of the Explorer was gaged before it was removed from the forming machine.

Another use is to determine the thickness of hollow aluminum extrusions and of parts while they are being chemically milled. In corrosion surveys it can measure thickness of the remaining metal.

Additional information on ultrasonic testing was provided by William C. Hitt of Douglas Aircraft Co., who told of a study to establish standards for ultrasonic testing of aircraft parts made of aluminum alloys, two titanium alloys and three magnesium alloys. Mr. Hitt urged engineers and others concerned with ultrasonic testing to secure a copy of the manual*. A new research project is being prepared to determine variables in 4130, 4340, and several stainless steels. It will be completed in about a year and will coordinate fatigue and tensile tests with ultrasonic response.

*WADC Technical Report 57-268, "Research and Development Leading to the Establishment of Ultrasonic Reference Standards for Aircraft Materials", It may be bought from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D.C.

Staff Report

New Method Speeds Annealing

Coils of carbon steel from cold mill are rewound to provide space between laminations. This speeds up heating and cooling, improves temperature uniformity. A recuperative method salvages heat from cooling coils for use in preheating cold coils. The new system promises a significant reduction in annealing costs, say its developers. (J23; 1-55; ST, 4-53)

THE MODEL in Fig. 1 on p. 98 illustrates the principle back of a new method for annealing cold rolled steel which its developers predict will save producers more than $2 per ton on products such as auto body stock. The arrangement shows a coil "opening" machine in process of rewinding a tight coil into an open coil prior to annealing. This permits hot gases to circulate completely through the coil giving faster heating and better uniformity.

Key to the new annealing concept, which was worked out by Lee Wilson Engineering Co., Cleveland, is the method used to expand (open) tight coils, index them through successive furnace stations and rewind them into final tight form. The surface area of an opened coil gives 200 to 1000 times the area for heat transfer compared with a tight coil. This gives annealing that's ten times the speed of a typical 4-stack system. The coils are partly heated by a recuperative system which transfers heat from coils being cooled to those being heated. By circulating 20,000 cu. ft. per min. of gas in the regenerative and cooling cylces and 40,000 cu. ft. per min. in the heating zones, a high degree of temperature uniformity is realized. The new system has been tested on a pilot-plant basis by annealing full-size coils which were shipped to auto companies for regular use.

A tight coil from the cold mill is fed around a tension block and attached to the winding block on the expanded coil table. A nylon string is inserted at the top edge of the coil and the coil is rewound so that the string separates the individual layers of steel. After the coil is completely expanded, the string is pulled out. By means of a special coil handler, the coil can be moved directly to the furnace or moved to a cleaning area where any oil may be removed by using exhaust gases from the heaters to vaporize it.

The clean coil is placed on a special platform straddling the coil handling car and driven into a purge chamber. After inert atmosphere gas or standard annealing atmosphere has purged the chamber, the coil-carrying car positions the coil and platform on the hearth. The car enters the chamber and the heating cycle starts.

Figure 2 is a model of the furnace labeled to show heating and cooling operations. It illustrates how the coils of steel are indexed around the rotary hearth in "lazy-Susan" fashion. The coil is heated by a recuperative system which transfers heat from coils being cooled to those being heated. Atmosphere gas picks up heat as it is pulled by a blower down through the cooling coil. These hot gases are transferred by a connecting duct to a cold coil, where heat is transmitted in the strip laminations. This first zone brings the temperature of the cold coil to about 450° F. in some 30 min. by using heat from the coil in the second cooling zone.

Next the coil is heated from 450 to 900° F. by a second recuperative cycle. A blower located over a coil in the first cooling zone pulls gases up through it and directs them down through the strip laminations of the coil being heated in the second heating zone. Here again the temperature equalizes in about 30 min. Thus, at the end of 1 hr., temperature of the

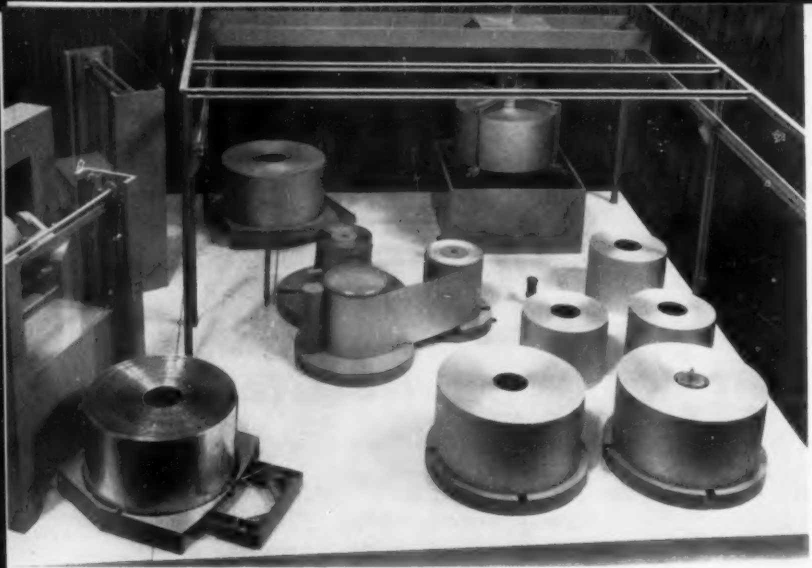


Fig. 1—Model Arrangement Shows Tight Coil Being Rewound Into Open Coil to Permit Hot Gases to Circulate Completely Through It

cold coil has been raised to 900° F. by using heat from coils that are being cooled. It is then moved into the first heating station.

Heating Stations — In the first heating station, atmosphere gas is circulated through a radiant tube heater with an output of 7,000,000 Btu. per hr. When the top edges of the coil in this station reach the required temperature, the coil is automatically indexed to the next heating station. This station, and the one following it, are served by a second heater with a capacity of 1,200,000 Btu. per hr., which provides any additional heat needed to bring the entire coil to a uniform annealing temperature of 1320° F. This heating, or soaking action, is maintained in a second indexing station and the gases are circulated from the smaller heater through the second indexing station to the first indexing station. This provides opposite flow direction to the gases in each of these stations.

Cooling Zones — As already brought out, heat transfers from the coil in the first cooling zone to the one in the second heating stage. The cooling coil drops from annealing temperatures to about 950° F. and then moves to the second cooling zone where it regenerates heat for the fresh cold coil. This brings the cooling coil to the 500° F. range. It then moves into a cooling chamber which operates on the same atmosphere gas as the rotary hearth. Gas is circulated with a 20,000-cu. ft. per min. blower through a 2,000,000-Btu. water tube-type cooler. Coil temperature drops to 250° F. and the coil is moved to the unloading station. It is then placed over a cooling grid, where air is drawn down through the laminations for cooling to room temperature.

The next step is to rewind the expanded coil. The strip is fed over the tension roll and attached to the block on the tight coiling table. After rewinding the coil is ready for temper rolling.

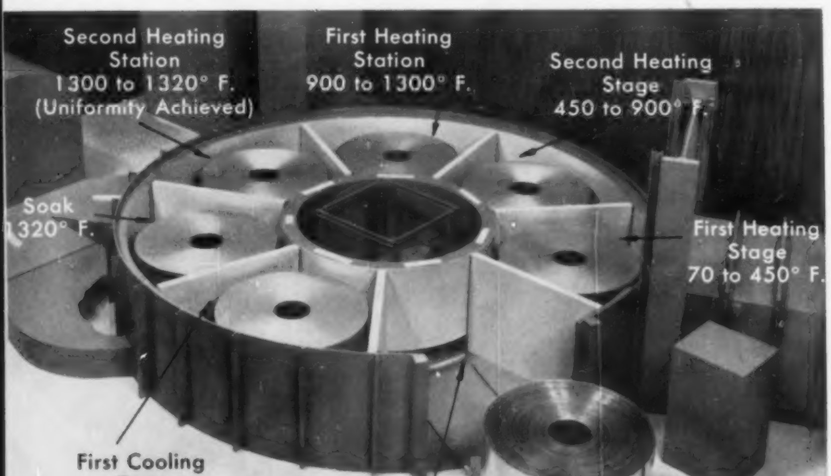


Fig. 2 — Coils of Steel Which Have Been Opened Are Indexed Around the Rotary Hearth in "Lazy-Susan" Fashion Through the Various Zones Indicated. A recuperative system salvages hot gases from cooling coils for preheating coils just entering the annealing process

Processing With Continuous Heating

. . . an Economic Appraisal

*By FREDERIC O. HESS**

The continuous furnace should be thought of as a processing tool. Many factors in its design and operation require a realistic appraisal. For example, rating a furnace on fuel efficiency and fuel costs can be deceptive. Most continuous furnaces today are not single-purpose devices and this must be considered in their evaluation. (W20h, W27, 1-61)

FREQUENTLY we have observed that economic factors are not adequately considered in evaluating the performance of projects involving furnaces. One big reason why this is true is that the continuous furnace is not placed where it belongs – that is, in the classification of a processing tool.

In other words, we contend that a continuous furnace is not just a brick-lined structure built to heat a material, and equipped with mechanical means to convey it. We have examples to show that rating a furnace on fuel efficiency and fuel cost can be deceptive; in fact, efficiency as applied to a furnace operation is totally misconceived if restricted to the ratio of heat input and heat absorbed. It is done every day, yet no one would rate the performance of an automatic screw machine on the ratio of connected horsepower to average daily power consumption. One can justifiably establish such "efficiency" ratios for a single-purpose operation as, for example, a compressor. But the facts are that most continuous furnaces today are not single-purpose devices, and should not be so considered and evaluated.

Heating Blooms

For the first example, we will examine the reheating of blooms in a steel mill. When rolling a large ingot into a bloom, the surface cools by radiation, as well as by frequent roll contact. Any attempt to finish roll this bloom into a product such as a railroad rail or bar would produce a defective product due to the non-uniformity of heat distribution throughout the bloom during these final rolling stages. Conventional practice has been to remove the blooms from the rolling process, charge them into batch-type reheating furnaces, and reheat and soak them for ½ to 1 hr. Then this reheated bloom is taken from the furnace and placed back onto the rolling mill table for final rolling. This practice involves at least two handlings of the steel by a mechanical manipulator and a series of batch furnaces. In spite of the long heating times, this does not produce entirely uniformly heated blooms because they must rest on a furnace hearth during reheating.

Figure 1 shows a continuous furnace between a blooming mill and a rail mill which performs this reheating at a production rate up to 198 tons per hr. The process is entirely automatic; the bloom temperature is controlled by a radiation pyrometer. No labor is involved; if no bloom enters the line, the furnace automatically goes on low temperature setting. The furnace is self-emptying, the bloom rolling on a conveyor.

In Fig. 1, a bloom which has a cross section of $9\frac{1}{2} \times 11$ in. is entering the furnace line. A reasonable value for the steel bloom, at this stage of processing, might be \$38 per ton. This figures out to \$7524 per hr., and for a 40-turn month, we arrive at a production value of \$2,400,000, which is more than 12 times the cost of the continuous reheating furnace line. The fuel consumption is 420,000 Btu. per ton, which calculates to a reheating fuel cost of 21¢ per ton.

*President, Selas Corp. of America, Dresher, Pa.

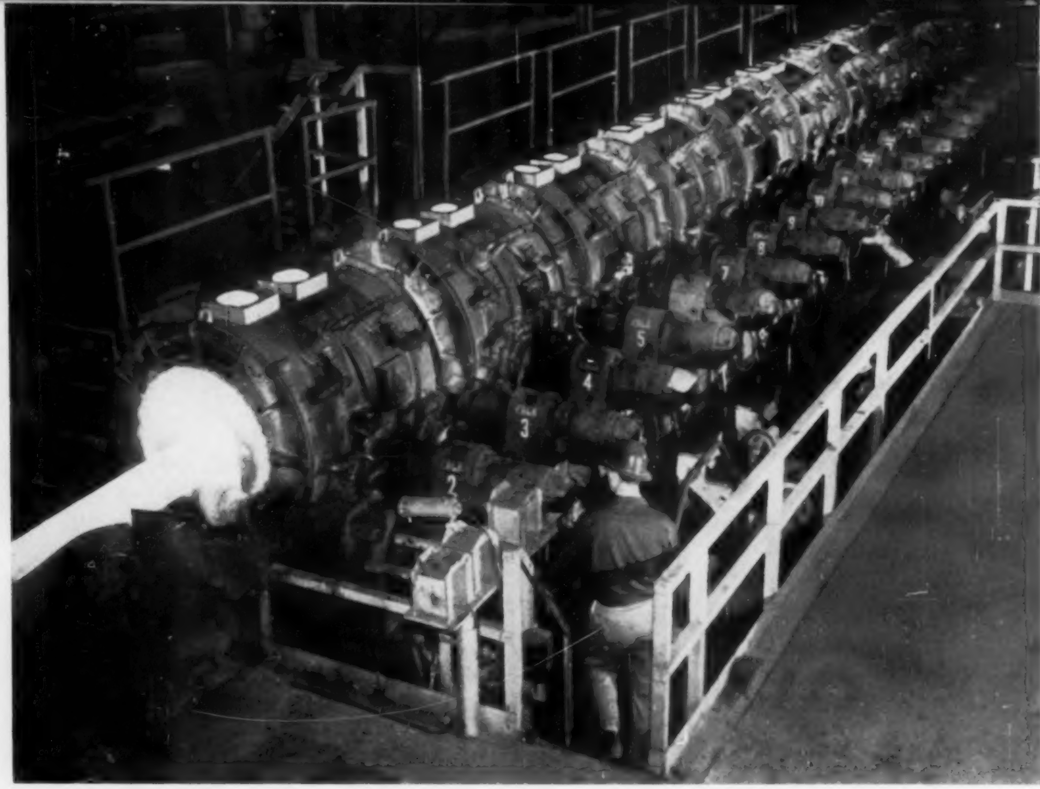


Fig. 1 – Continuous Reheating Furnace Links a Blooming Mill to a Rail Mill. It's entirely automatic and can handle up to 198 tons per hr.

Now, let's look at the economics of this installation. Our fuel cost amounts to less than 6/10 of 1% of product value. For the 40-turn month, this represents about $13,300. These costs are obtained without heat recuperation. Suppose we add recuperation and increase our fuel efficiency by 50% – an optimistic expectation. This would save $4440 per month but at a substantial additional equipment cost. More than three years would be required to pay for the recuperator cost from fuel savings – neglecting entirely the inescapable maintenance cost of recuperative equipment.

Fuel efficiency is not of major consequence in the economy of this process, but material handling is. It is generally agreed that today it costs about $2 to pick up a ton of hot steel, transport it 100 to 150 ft. and set it down again. On this basis, eliminating two handlings, we save $396 per hr., or pay for the new furnace entirely in less than 1½ months, or 60 turns. After that, a saving of $4 per ton is realized from this "paid for" continuous furnace, since the operating costs should certainly not be higher for the continuous furnace than they are for a battery of batch furnaces. Beyond this, a reheating time of 3 min. against ½ to 1 hr. at 2250° F. accounts for a scale saving of some 1½%, or 3 tons per hr., at $38 per ton. This means $36,680 per 40-turn month or three times the total fuel cost.

Better Quality

We could extend this study into better product quality because of more uniform bloom temperature, reduced grain growth, less decarburization due to short heating time, and many other factors of some consequence. But the facts given should suffice to substantiate our contention that, on projects of this nature, fuel efficiency alone is often inconsequential in comparison to other factors. Design considerations and quality of construction are also important. Production stoppages, due to mechanical or operational failure, totaling less than 30 hr., can result in a loss in product value equal to the total equipment cost. This means that, if continuous furnaces are interconnected with mill or other processing operations, reliability and performance must receive top consideration.

Normalizing After Welding

The equipment shown in Fig. 2 is similar to the bloom furnace but it was installed for an entirely different purpose. Management of a modern electric weld pipe mill wanted to normalize the pipe after welding to improve mechanical properties and to make the product suitable for

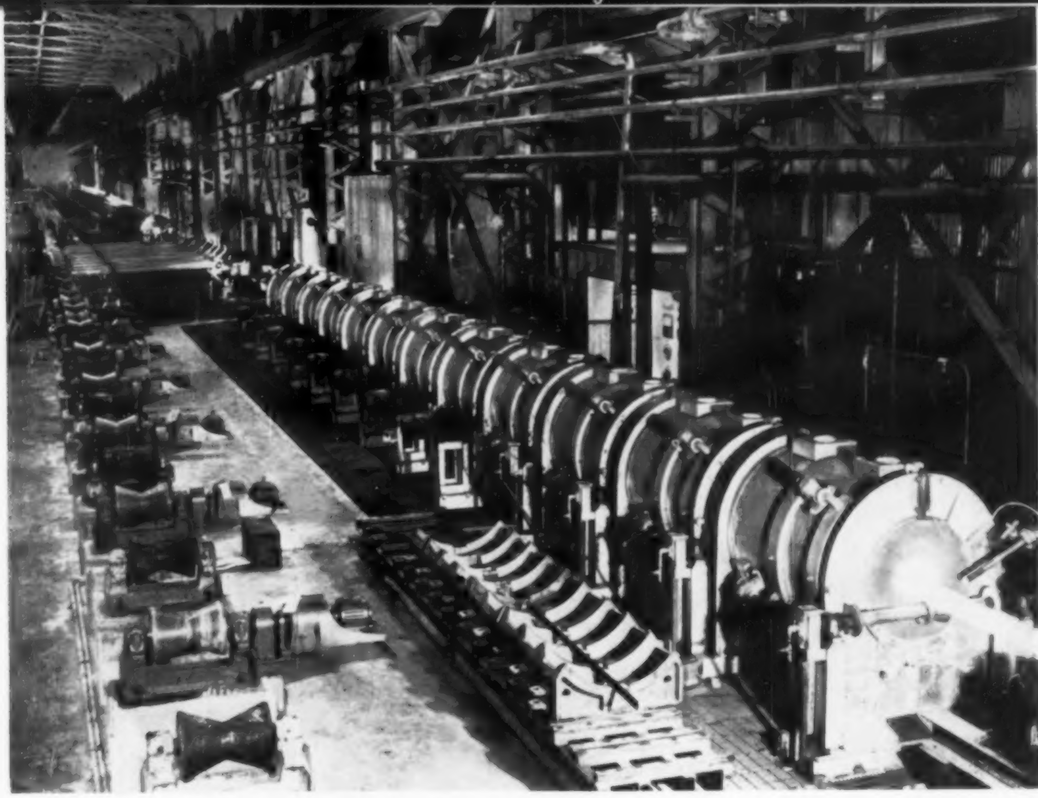


Fig. 2 – This Production Line Starts With Plate and in a Straight Uninterrupted Flow Automatically Forms, Welds and Normalizes Pipe, and, if Desired, Stretch-Reduces

oil industry requirements. Extensive tests proved that short-cycle normalizing would give the desired properties; therefore, a continuous furnace line could be considered practical.

The normalizing line is actually in the background of the picture, while the furnace line (in front) of duplicate design heats the same pipe to 1800° F., the temperature required for the in-line stretch mill which follows. This one continuous production line starts with plate, and in a straight uninterrupted flow automatically forms, welds and normalizes pipe and, if desired, stretch reduces the pipe to various smaller sizes.

The normalizing furnace line in this particular plant shows a fuel cost of 39¢ per ton. Production amounts to 90 tons per hr. which, at that stage of processing, is valued at some $100 per ton, or $9000 per hr., or $72,000 per turn. Less than 40 hr. of production or of forced shutdown represents the cost of the continuous furnace. The fuel cost for heat treating is 4/10 of 1% of product value. Scale is of no consequence, as evidenced by the direct run into the reducing mill. Uniformity of treatment for every foot of pipe is assured because of continuous passage through identical furnace conditions.

Another installation in pipe processing is for making high-strength deep well casing. By precise heat treatment, it is possible to raise mechanical properties of low-alloy steels to a level which makes them suitable for the extreme demands of the pressures and depth of our oil wells. Casings having a tensile strength of 110,000 psi. and as high as 140,000 psi. are produced on a continuous basis.

The casing enters the furnace line, is heated to hardening temperature (1650° F.) and is then immediately quenched. Rapid rotation is applied during the entire forward movement to maintain straightness. Following the quench, the casing is drained of any residual quench water, and then tempered in a similar furnace line. Both heating processes are short-cycle and produce a fine grain structure with optimum mechanical properties.

With this heat treatment, the value of the product is increased by some $50 per ton. The line is capable of producing 7 tons per hr. of medium-size pipe, which means a $350 per hr. net increase in value of a product which is worth, as it enters the process, $130 per ton, or a total of $910 per production hr. During a 40-turn month, an additional value of $112,000 is created, which is about one-fourth the total equipment cost. The total product value per month at the exit is more than the cost of the equipment. If

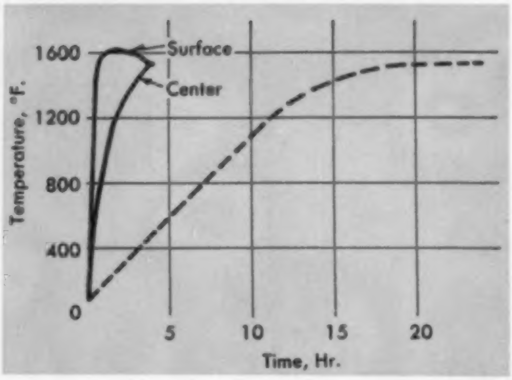


Fig. 3 – The Dotted Curve Shows the Heating Cycle Once Specified for an 18-In. Thick Die Block. The solid lines represent the heating operation now performed on the same block. The cycle was cut to one-sixth the time formerly required

this is contrasted with the first example (bloom reheating line), where product value per month was more than 12 times the furnace cost, the importance of complete economic evaluation can be appreciated. Here again, fuel cost is a minor factor in relation to product value; many other items enter into processing costs.

Fast Heating of Die Blocks

Past experience seems to have established certain facts about heating potentials, which were accepted as rules and basic standards of design. For example, large steel sections such as die blocks could only be heated at certain rates. To be specific, 1 hr. per in. was the rule for heating steel to forging or rolling temperature. Unfortunately, such "experience rules" were based on a misinterpretation of results and facts. Nonuniform heating techniques were translated into metallurgical results and retarded progress.

The dotted curve in Fig. 3 shows the heating cycle once specified for an 18-in. thick die block. The solid lines represent the heating operation now performed on the same die block. Thousands of tons of first-quality blocks have been produced at one-sixth the former operating cycle. One furnace produced the same tonnage as formerly came from seven furnaces – with less fuel, less scale, less labor and less material in process. The reason: uniform heating and program control regulated for heat absorption capacity and maximum permissible temperature. Here, fuel cost is about $1.80 per ton, but product value in six turns exceeds the cost of the furnace, and one spoiled furnace charge is worth more than 60 times the total fuel cost.

The same point is proven with roll hardening furnaces, which carry out the hardening cycle in 2 to 4 hr. at only 85¢ per ton fuel cost. In this example, one single charge, a 54-ton roll, is worth far more than the furnace equipment. No wonder then that uniformity of heating, control, surface effects, maximum temperature and heating rates are factors which must be well coordinated to protect such a valuable charge.

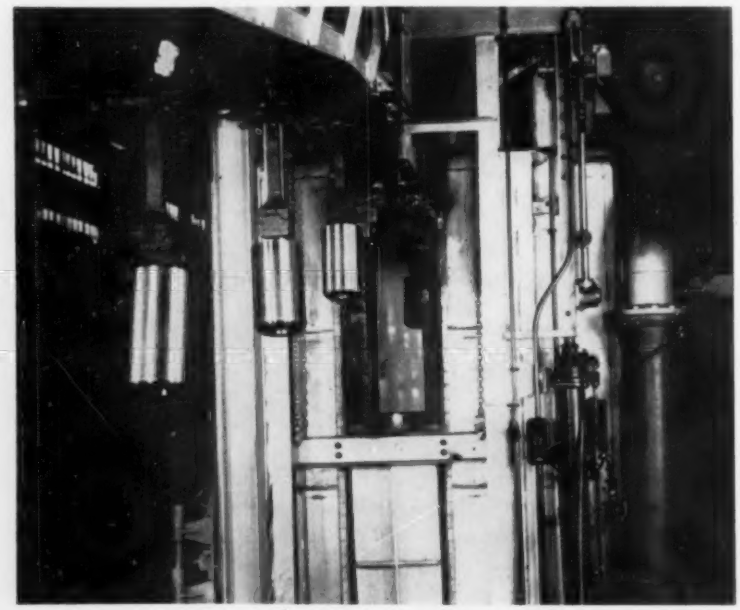
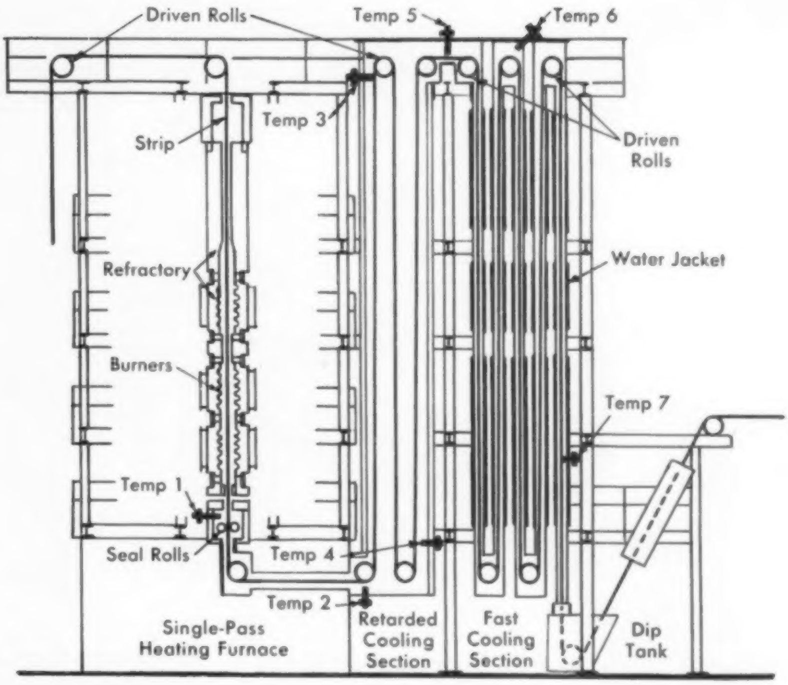


Fig. 4 – Extrusion Billets Are Hung on Welded Studs and Carried Through the Furnace by a Continuous Conveyer at the Rate of 8 Tons per Hr.

Fig. 5 – Schematic Layout of Equipment for Continuous Annealing of Steel Strip. In one single downward pass, the strip is heated to annealing temperature. It then enters two controlled cooling sections



The benefits of continuous heating carry over to heavy sections. The steel and alloy billet heating furnace shown in Fig. 4 provides a good example. For fast and uniform heating, the billets are hung on welded studs, and carried through the furnace by a continuous conveyer, at the rate of 8 tons per hr. The billet touches no wall or hearth, and thus is in an ideal position to be heated uniformly – a basic requirement for the extrusion process which follows. Actual heating is done by radiant burners in the sidewalls; only the products of combustion – no flames – are inside the furnace chamber surrounding the billet. Radiation supplies 80% of the heat. The product value in 7 hr. of operation at rated capacity represents more than the cost of the furnace – due to the high price of the extruded alloys. The furnace is only a small part of the total installation – far less than 10% – but variation of a few degrees in billet temperature will cause the product quality to be outside commercial dimensional tolerances.

Continuous Annealing

Going from heavy sections to light sections, we also find radical departures from conventional practices and concepts. Continuous bright annealing of steel is now an accepted process. Today, it is in operation at speeds up to 1000 ft. per min. on steel strip 0.010 in. thick by 48 in. wide, with higher speeds contemplated. These installations require a high capital investment, $1,500,000 or more, but are being justified primarily because of product improvement. When tin-plate stock is annealed in coils or sheet packs, long annealing cycles (up to 200 hr., depending on size of charge) are necessary to penetrate the coil. This means there is an appreciable difference in time at temperature between the center and outside of the coil. In the continuous process, the time cycle has been reduced to 4 sec. heating and 45 sec. cooling; each foot of strip goes through identical treatment conditions.

The more uniform product is beneficial to uninterrupted operation of high-speed can machinery. Also, this fast treated steel is harder by our hardness test methods than conventionally annealed strip. Yet contrary to "the book", this harder steel has better deep drawing qualities which, with its increased stiffness, permits the use of lighter gage steel for tin cans and containers. The continuous furnace thus gives a result considerably beyond mere heating to annealing temperature.

The equipment arrangement is illustrated in Fig. 5. In one single downward pass the strip is heated to annealing temperature. The furnace unit is direct fired, that is, the strip is exposed to the products of combustion issuing from the radiant burner panels – yet, again contrary to

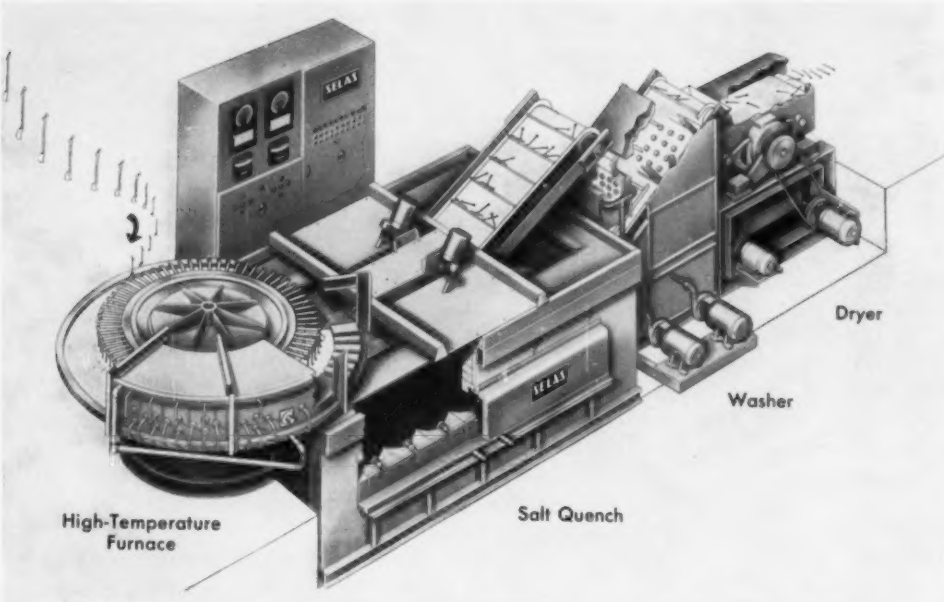


Fig. 6 – This Automatic Heat Treating Machine Austempers 5000 Small Parts per Hr. for Use in Business Machines

expectations, by control of the combustion process and by using only seconds of heating time, no oxide is formed. The strip then enters a slow cool section which employs a nonoxidizing atmosphere. There are four lines like this, side by side, in one plant. One of these lines has produced an average of 17 tons per hr. during a month. On this basis, one such line (which is not the highest speed line in operation) has the capacity to handle, conservatively, a product

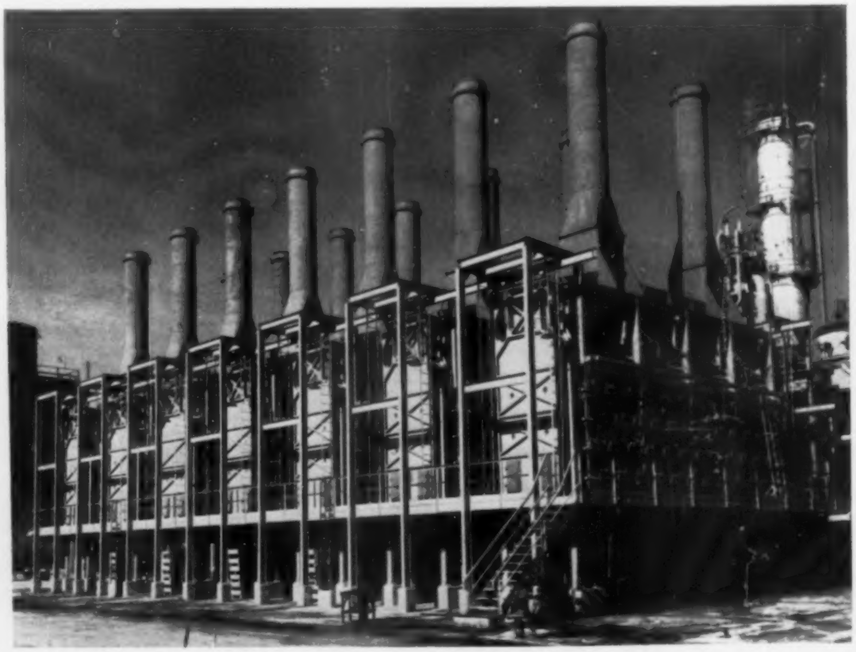


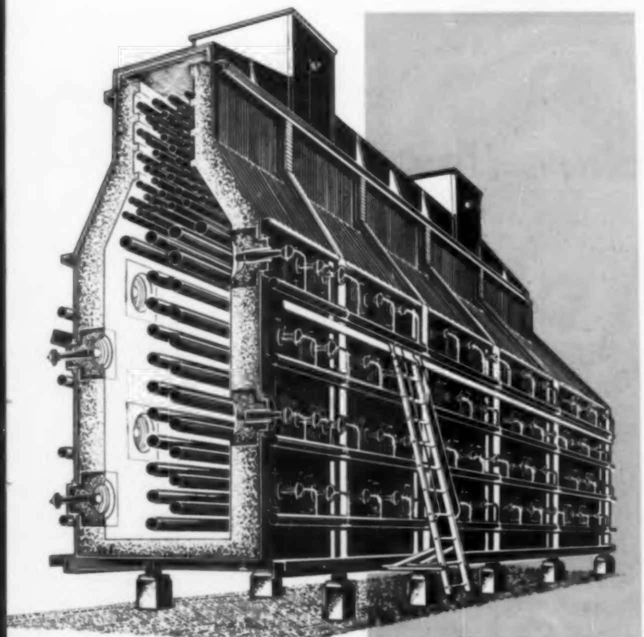
Fig. 7 – This Battery of Seven Pyrolysis Furnaces Cracks Hydrocarbons to Give Ethylene. Also shown is close-up of individual furnace. Hydrocarbon feed stock enters the tubes in the narrow top section where it is preheated by waste gases. Cracking takes place in the center row of radiant burners, spaced to give a precise time-temperature relationship

value of over $800,000 per month, which is almost double the cost of the continuous furnace equipment. The fuel cost for this production amounts to $9400 per month – which, with a minor addition to the existing equipment, can be lowered to less than 1% of product value. Value of product alone represents over $1200 per hr. Again, this puts emphasis on simplicity and reliability of the equipment for any continuous operation.

Business Machine Parts

A relatively small production line for heat treating typewriter or calculator keys is shown in Fig. 6. The parts are small, precise steel stampings which cannot be distorted during heating and handling. They must be clean for tumbling and plating – the last steps in the production process. Any attempt to straighten faulty parts has proven uneconomical.

This continuous automatic heat treating machine can produce 5000 keys or levers per hour which, at this point, are estimated to represent a product value of $120,000 per 40-turn month. This is about 1½ times the equipment cost with a fuel cost of a little over $400. If the fuel cost were entirely eliminated, it would have less influence on the sales price of the product than a spoilage of but 500 keys of the total monthly production, or only 6 sec. out of 320 hr. of monthly production.



Pyrolysis Furnaces

As a last example of the design of a continuous furnace and its economic implications, let's leave the metals industry for the petrochemical field. Here we can illustrate why increasing attention is being paid to the optimum mechanical properties of metals, and also we can show the striking effects of controlled heat processing cycles. Ethylene is the raw material for the versatile plastic, polyethylene. Figure 7 shows one plant's battery of seven identical heating units which are called pyrolysis furnaces because by heat application, a pyrolytic cracking of hydrocarbon feed stock takes place.

The feed stock enters the tubes in the narrow top section where it is preheated by waste gases. Cracking takes place in the center row of horizontal tubes in the furnace chamber fired by multiple rows of radiant burners, spaced to produce a precise time-temperature curve of the material passing through the bank of 6-in. diameter alloy tubes. There are about $500,000 worth of alloy and steel tubes in these heaters. Improper heating will shorten their life and require frequent replacement. Since the product is worth about $130,000 per day, any shutdown for tube replacement is an expensive operation. Shutdowns can also be caused by coking inside the tubes because of improper cracking, largely due to improper time-temperature cycle or local overheating of tubes.

The net increase in product value, or the difference between the value of charge stock and value of products after allowance of all operating cost and charges, is in the order of $50,000 per day. It is no wonder then that operators are concerned about high-quality tubing, sound fabrication and precision control. The design here plus sound operation extended the continuous operating periods of a heater from about one month to three months, and this improvement alone pays the furnace cost in less than one year of operation.

Split seconds at temperature are of critical influence in the conversion of the hydrocarbon molecules from a relatively low-value charge stock to different high-value products. Basically, in metal heat treatment, too, we are dealing in molecules. These molecules also are influenced not just by temperature, but by a time-temperature cycle. Future research can teach us much—if we approach it open-mindedly with a desire to investigate all phases of heat processing instead of heating only.

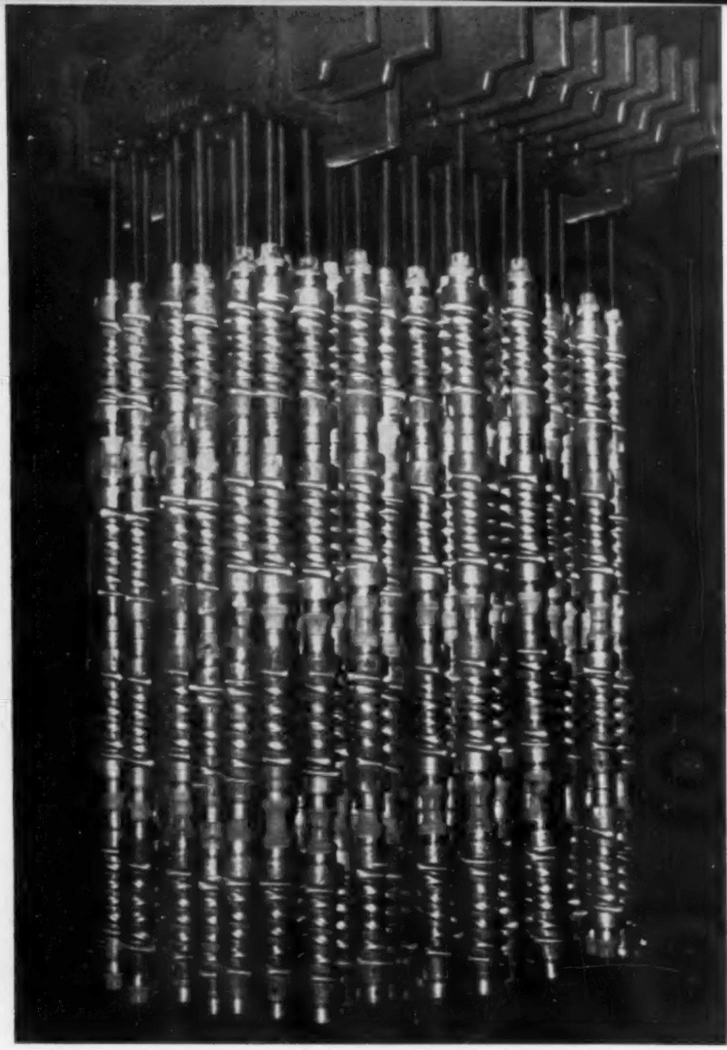


Fig. 1 — Steering Cams Are Strung on Rods, Then Suspended From a Cast Alloy Fixture for Carburizing

Cast Alloy Fixture Has Long Life in

Ross gear & tool co., Lafayette, Ind., carburizes 300,000 to 400,000 lb. of steering assembly parts each month. Of all the parts that go through the carburizing cycle, the worm-type cam is handled in greatest volume. The cams are made of alloy steel bar stock, S.A.E. 8620; some 1500 lb. per load are strung on rods and suspended from the cast heat resistant alloy fixture as shown in Fig. 1. Vertical suspension of these parts must be maintained by the fixture throughout cycles of long exposure to high temperature and thermal shock during sudden quenching. The fixture must not distort under these operating conditions. All parts carburized at Ross are suspended from this special fixture.

Carburizing Cycle

At the start of the carburizing cycle, the fixture with the cams is lowered (Fig. 2) into one of four radiant tube, pit-type controlled atmosphere furnaces (built by Surface Combustion Corp., Toledo, Ohio). About 2½ hr. is required to bring

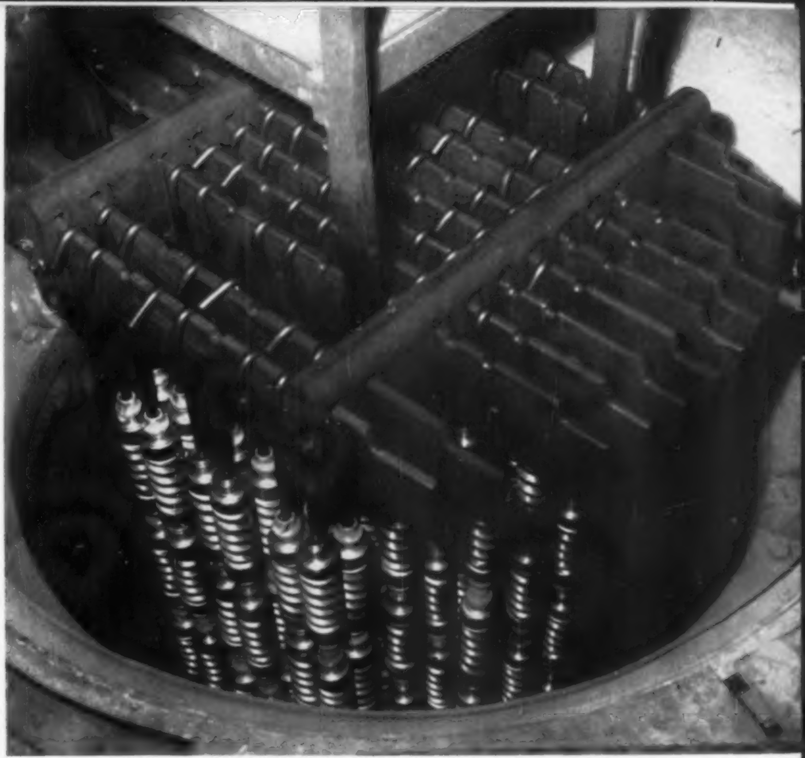


Fig. 2 – Cams and Fixtures Are Lowered Into the Controlled Atmosphere Carburizing Furnace. All parts to be carburized go through the same type of furnace, suspended from this special fixture

The Problem: Find a heat treating fixture to support 1500 lb. of steering gear parts during repeated carburizing and oil quenching. .The Solution: A unique fixture design, utilizing Alloy Casting Institute Type HT heat resistant castings. (W27p, 17-57, J28g; SGA-h, Ni, Fe)

Thermal Shock Service

*By E. A. SCHOEFER**

the furnace and load up to heat; in a typical cycle, the cams are held at 1700° F. for 8½ hr. The furnace temperature is then lowered to 1575° F. and held for 1 hr. to equalize the work temperature. During the entire furnace cycle, a carburizing medium consisting of 265 cu.ft. per hr. of an enriched RX atmosphere (CO_2, less than 0.1%; CO, 18%; CH_4, 2%; H_2, 42%; dew point about + 10° F.) is used; this includes 15 cu.ft. per hr. of natural gas. After removal from the furnace, the work and the fixture are direct quenched in oil.

The heat treating operation is designed to obtain hardness of Rockwell C-58 to 63, and a minimum case depth of 0.045 to 0.075 in., depending on the size of the part. Because the cams are critical to the proper functioning of the steering assembly, they are given a 100% hardness test.

Fixture Design

Since the fixture (Fig. 3) on which the work is suspended goes through the same cycle as the cams, it must resist the high temperatures and thermal shock of quenching. The fixture is designed as a group of individual "leaves", loosely pinned together through box members in the form of a flexible grid. The leaves – some as long as 39½ in. – are cast of Type HT alloy (Alloy Casting Institute designation) which is nominally 35% Ni, 15% Cr, about 0.50% C, and the balance iron with small amounts of silicon and manganese.

During the heat treating cycle, the leaves rest on a Type HT alloy casting which serves as a support ring in the furnace. The high-alloy cast leaves in the fixture have sufficient strength to sustain the load without need for bracing which would cause distortion from thermally imposed stresses. The slotted hollow box members, also cast of Type HT alloy, serve as spacers to keep

*Executive Vice-President, Alloy Casting Institute, Mineola, N.Y.

the leaves properly positioned laterally while permitting them freedom to expand longitudinally. These castings also act as girders to support the leaves when the load is lifted from the furnace for transfer to the quench tank. This articulated construction has the added economic advantage of prolonging service life of the fixture since individual components can be replaced if necessary.

Type HT cast alloy is specified for the fixture because of its resistance to carburizing atmospheres and its ability to withstand thermal shock without severe distortion. At about 1700° F. in air, for example, steel corrodes more than 500 times as fast as HT alloy. Most other alloys with comparable corrosion resistance are not as strong or do not resist thermal shock as well. Of the usual heat resistant alloy grades that have good thermal shock resistance and are economically suitable for this design, Type HT is the strongest at the operating temperature of 1700° F. Cast Type HT has about double the strength of the comparable wrought alloy (Type 330 stainless steel) at this temperature.

Furnace Castings

The pit-type carburizing furnaces (Fig. 4) are heated by gas-fired radiant tubes. No muffles are required, which means maximum charge per load is attained. This type of furnace also allows vertical suspension of cams. A single furnace uses 16 U-shaped cast high-alloy radiant tubes, each of which weighs about 40 lb. At the bottom of the furnace, a six-blade cast high-alloy fan circulates the carburizing atmosphere, for uniform heating of the charge and close control of temperature.

Since moderately increased carbon content does not significantly affect its high-temperature ductility, cast HT alloy is especially useful in carburizing operations. By increasing the silicon content to 1.6%, additional protection against carburization is possible.

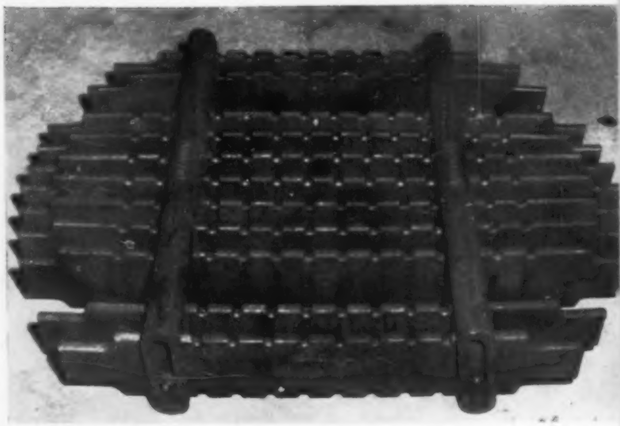


Fig. 3 – Heat Treating Fixture of Cast Type HT Alloy Used to Support Steering Gear Parts During Carburizing. The cast "leaves" are pinned together to form an articulated grid, and can be replaced individually, when necessary

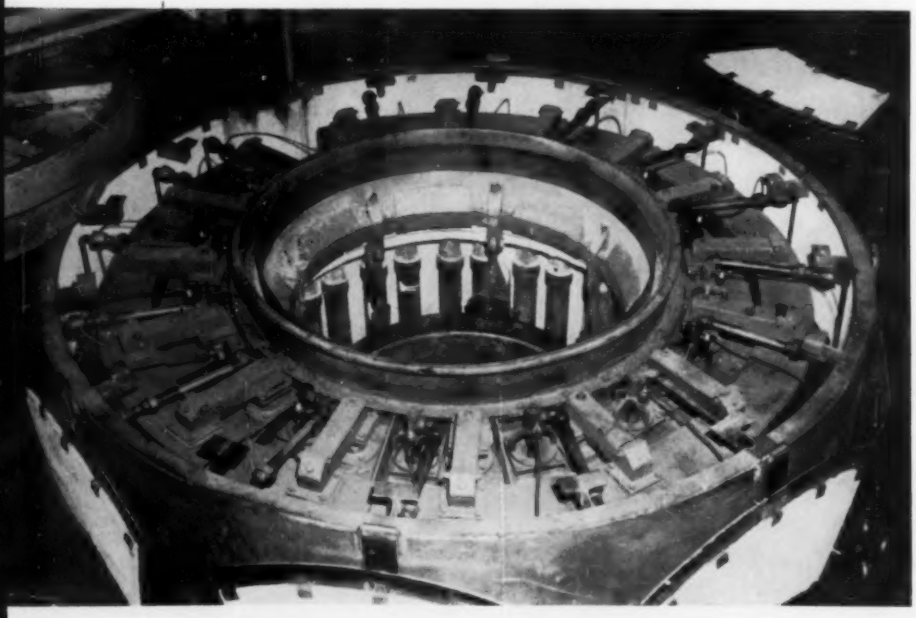


Fig. 4 – During the Heat Treating Cycle the Leaves in the Fixture Rest on an HT Alloy Casting Which Serves as a Support Ring in the Furnace. The furnace is heated by 16 U-shaped radiant tubes, and the atmosphere is circulated by a six-blade fan. Both the tubes and the fan are made of Type HT cast high alloy

Detection of Bomb Tests

Many believe that if future nuclear tests can be banned for a definite time, we would be making a good approach to the larger problem of international disarmament. The questions then would be, "Could such an agreement be adequately monitored? How can you know when and where a nuclear explosion occurs?" The following bears on those questions. It is an extract, with permission, from "Detection of Nuclear Weapons Testing", by Jay Orear, assistant professor of physics, Columbia University, in *Bulletin* of the Atomic Scientists, March, 1958, p. 98. Prof. Orear notes: "Since I have no access to classified material, I am in the fortunate position of being free to say anything."

APPARENTLY, nuclear explosions can be made of any size – roughly, "large" (fusion), "nominal" (fission – a Hiroshima-type bomb of about 20,000 tons TNT equivalent), a "subnominal" (down even as small as a firecracker). They may be tested anywhere – far above the atmosphere, within the atmosphere, at ground level, under water, or far underground. Since many of the Nevada tests are "subnominal" (1000 to 3000 tons TNT equivalent), one concludes that low-yield tests are useful modern weapons; any agreement and monitoring system should include them.

Four effects of atomic explosions have been used for detection: Electromagnetic radiation (visible light and radio noise), waves of air pressure, seismic waves, radioactivity in the air. The third will detect deep underground tests.

Detection of the visible light at distances up to within 300 miles is quite simple. One merely points a photocell at the sky; anytime of day or night a distinct light pulse will be observed. The same mechanism which gives twilight when the sun (or bomb) is below the horizon will give a glow in the sky due to the nuclear explosion. Because of the large number of photons involved, one can detect light pulses of very small intensity.

If the explosion is well above the atmosphere, the shape of the light pulse will be different, but there will still be plenty of visible light generated when the X-rays hit the upper atmosphere.

Waves of air pressure (acoustic waves) can be detected by sensitive microbarometers. Data from several stations locate and time the test, and also measure the size. Except for deep underground explosions, very high altitude tests, and tests of subnominal yield, nuclear tests can be so detected at very large distances.

All tests, whether underground or not, cause **seismic waves** which can be detected up to a certain distance by seismographs. These techniques tell the location and time of the explosion, and determine its size if underground.

As with the acoustic wave, the seismic wave cannot be detected at large distances for subnominal tests. For example, the underground Nevada test of 1957 (1000 to 3000 tons TNT equivalent) was not detected in the eastern United States. However, it was detected 300 miles away and the signals can be distinguished from natural earthquakes: The blast gives a sharp longitudinal pulse, while an earthquake gives a signal of much longer duration, predominately transverse, and from a deep source.

Radioactivity – Considerable publicity has been given the analysis of air streams for unusual radioactivity. While future bombs may emit no radioactive elements, "100% clean" is a practical impossibility. There is sufficient neutron-induced activity in the bomb shell and atmosphere to detect – except in deep underground tests. Because of the rapid decay of these minimum radioactive products, detection would be difficult more than 1000 miles away.

Detection program – Even tests which could escape detection outside the U.S.S.R. could be detected if about 25 ground monitoring stations (with heliometers, barometers and seismographs, continually recording) could be uniformly distributed over the Soviet Union. Then any test would be within 300 miles of at least one station and usually be within 500 miles of four stations. This would make it practically impossible to violate an agreement which suspends the testing of all nuclear weapons unless they are within an order of magnitude of conventional weapons.

The objection that these minimum monitoring conditions would interfere with a nation's internal security is not valid – provided the U.N. personnel are confined to a monitoring station located in civilian territory. Adequate inspection can therefore be provided without interfering with a nation's internal security. Apparently Russia recognizes this feature of a test-ban agreement, since it was the Soviet delegate who proposed scientific control posts. Whether this means that 22 stations in the U.S.S.R. would be acceptable is unknown. Apparently the Western delegates did not try to determine just what would be acceptable.

Staff Report

Pulse of the Nation's Welding

The metal joining field bristles with problems. Workers are seeking a better understanding of porosity, brittle fracture, residual stress, and the mechanism of brazing. These and other matters, including a look at the Welding Show, are summed up in this report. (K-general)

FROM THE ANNUAL MEETING and show of the American Welding Society, held April 14 to 18 in St. Louis, Mo., several trends emerge: In technical sessions, much emphasis was placed on the problems of porosity, strength and ductility, brittle failure, brazing metallurgy, and nuclear energy applications. Highlights of the show included a contour welding device, new types of semiautomatic welding units, several flux-cored electrodes, and a magnetically coated electrode combination.

Porosity – Five papers were concerned with porosity and several others mentioned it. A paper by William Green, M. F. Hamad and Roy McCauley (Ohio State University), "The Effects of Porosity on Mild Steel Molds", took an empirical approach. Essentially the authors measured porosity as a percentage of total cross section and then proceeded to test various percentages by tensile, bending and impact tests. Results indicate that the cross sections of the welds tested could be reduced by porosity up to 7%, without materially changing the mechanical properties. The authors claim that shape and distribution pattern of the pores do not cause significant differences.

A problem often encountered is open void porosity or "leakers" in welded joints. Defects of this nature are especially serious in containers and pressure vessels. Quite often the source of trouble can be traced to electrode composition or coating. James T. Lapsley, Jr. (University of California), in his paper, "Effects of Steelmaking Practice on Submerged-Arc Weld Porosity", took a searching look at the problem from the standpoint of materials used. Low-carbon steel representing four openhearth deoxidation practices (aluminum-silicon semikilled, silicon semikilled, aluminum capped and mechanically capped) were studied. These were submerged-arc welded following recommended procedures. Welds were radiographed and the porosity was evaluated by A.S.M.E. boiler code standards. Although porosity varied with deoxidation practice, it was, on the average, less than porosity caused by inferior weld preparation. All heats displayed greater pore formation in butt welds made from as-rolled, sheet edge material in contrast to butt welds from material having edges sheared or slit from sheet. (This could be significant in welding tube out of skelp.)

Contamination – It is well known that atmospheric contamination of the molten weld metal will cause serious porosity. Fred R. Collins (Alcoa Research Laboratories) discussed the nature and causes of weld porosity in his paper, "Porosity in Aluminum Alloy Welds". He measured contamination by adding (in separate tests) measured amounts of oxygen, chlorine, nitrogen, hydrogen, carbon monoxide and several other gases to the argon shielding gas. Only oxygen and chlorine were effective in reducing

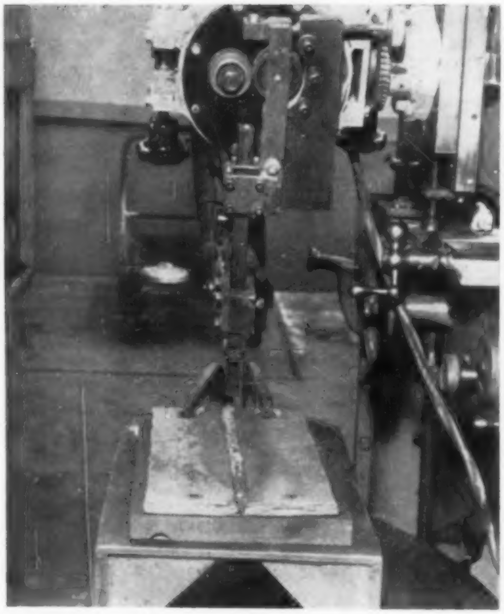


Fig. 1—At the Torch Nozzle, the Magnetc Field Surrounding the Welding Wire Magnetically Attracts the Flux to the Wire. Simultaneously the CO_2 shielding gas emerges from the nozzle. (Courtesy Linde Co.)

porosity. The other gases either increased porosity, gave poor wetting action, or caused excessive oxidation. Additions of oxygen up to about 2% decreased porosity slightly and increased penetration, but increased surface oxide. Chlorine, in additions up to 0.10%, decreased porosity but it is corrosive and may cause operator discomfort.

Additional tests made on artificially gassed plates were compared with thoroughly degassed samples. Welds in degassed plates were sound; those in artificially gassed samples were porous. This seems to bear out the supposition that weld porosity was caused by agglomeration in the weld area of gas contained in the artificially gassed parent metal samples.

Mr. Collins also investigated various mixtures of inert gas. His opinion: Mixtures of 65% helium, 35% argon gas produce a more stable arc than either pure argon or pure helium. He finally cautioned that no good welds can be made on dirty or oily aluminum plate – good advice any time.

In their presentation, "Cracking Associated With Porosity in Titanium Welds Over 0.125 In. Thick", Robert Olsen and James Gates (North American Aviation Co.) related cracking to porosity when a number of microscopic transverse cracks were discovered running directly through pores. The welds were made with an inert-gas, tungsten-arc welding unit. Although the authors did not establish with any degree of certainty the mechanism of cracking, they were able to eliminate the problem by changing to an inert-gas, metal-arc welding unit, using various combinations of filler wire. This led them to conclude, somewhat obviously, that the cracking must have been caused by some inherent characteristic of the tungsten-arc process.

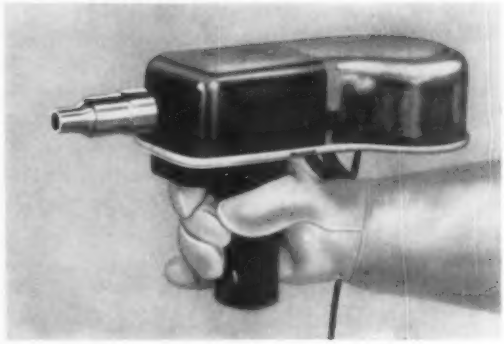


Fig. 2—A Streamlined, Hand-Held, Semiautomatic Welding Gun. Shielding gas and electrode wire are fed simultaneously from the nozzle. Drive rolls and wire supply are contained in the gun. The loaded gun weighs about 4 lb. (Courtesy Air Reduction Sales Co.)

High-Nickel Alloys – More help on porosity problems come from the paper "Control of Porosity in High-Nickel Welds", by George Pease, Robert Brien and Pierre Le Grand (International Nickel Co.). The authors found that certain gases are pore formers, and established the extent of their damaging influence. They gave a few good rules to follow in order to avoid contamination.

Of several gases studied, nitrogen was the most potentially damaging to the soundness of high-nickel alloy weld deposits. As little as 0.1 to 0.2% will induce traces of porosity. Chromium-bearing high-nickel alloys were relatively immune. Carbon monoxide was the second potential source of unsoundness. Additions above 5% damaged Monel and nickel welds, but had no effect on Inconel. Oxygen additions of 6% caused porosity in Monel and nickel. Carbon dioxide vigorously attacked the tungsten electrode. The authors conclude that welding procedures are important for porosity-free welds. Even though inert gases used are of maximum purity, it is imperative to use a short arc and an ample flow of gas.

Strength and Ductility – There is a need for a better understanding of the fundamentals of strength and ductility and of the mechanism of brittle failure. A number of papers dealt with problems in these areas. In some instances, authors only discussed the properties and defects of the weld deposits; in other papers the emphasis was placed on properties and defects in unwelded material.

In "A Study of the Factors Effecting the Strength and Ductility of Weld Metal", C. Marvin Wayman (University of Illinois) and Robert D. Stout (Lehigh University) were looking for fundamental answers, particularly for steels. Early in their study, they established that weld properties are independent of process, and that variations in current, voltage and travel speed may be considered as one variable, the energy input. Stronger, less ductile welds were produced at low values of energy input, while at high energy input the inverse was true. Preheating up to 800° F. had little effect on the mechanical properties.

The authors studied the effect of carbon content by depositing weld metal in ingot iron, A 212 steel, and eutectoid steel. The yield and ultimate tensile strengths increased with increased carbon content, and the yield ratio decreased slightly at all carbon levels. The authors established experimentally (by comparing the effect of restraint on similar welded steel and welded copper-base plates) that the presence of plastic strain during cooling is responsible for the intrinsically high yield strength and ratio in weld metal.

In his paper, "Effect of Welding Speed on Strength of 6061-T 4 Aluminum Joints", William L. Burch (Bell Aircraft Corp.) took a long and hard look at this important variable. He concluded that welding speed is the most significant factor influencing strength; as the speed increases, the strength increases rapidly up to a certain point, after which improvement is slight. He related welding speed to heat input. This relationship shows why joint strength improves with higher speed. Heat input expressed as watt seconds per inch of weld at low speeds was very

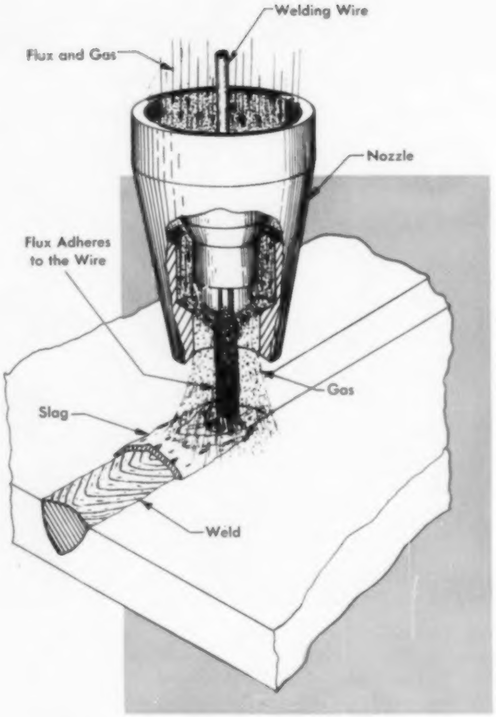
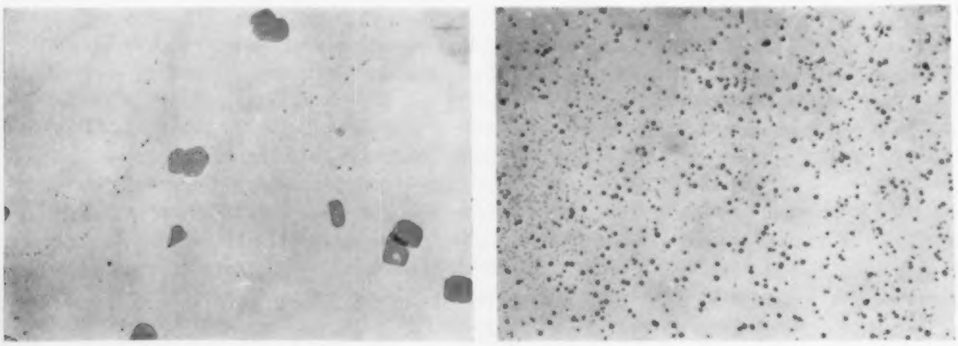


Fig. 3–Setup for Submerged-Arc Welding of Uranium. Plate was welded using d-c. straight polarity, 500 amp. and 28 to 30 v. The 3/16-in. consumable uranium electrode was coated with silver

Fig. 4–Microstructure of the Weld and Parent Uranium Metal. Large carbides are plainly visible in the parent metal, while in the weld metal the carbide particles have been broken up, perhaps by arc energy force



high, but, as the speed was increased, the input dropped sharply, then leveled out at high speeds. Result: the plate and jig remain relatively cool and quench the heat-affected metal more rapidly. Mr. Burch also studied the quenching effect of the jig. Conventional water cooled jaws gave the highest strengths, but even when the base plate was insulated from the jaws so that the quench effect was achieved by the base plate alone, strengths were still held within acceptable limits.

Brittle Failure – A team of scientists, R. P. Sopher, P. J. Rieppel, D. C. Martin (Battelle Memorial Institute) and A. L. Lowe, Jr., (Babcock and Wilcox Co.) are continuing their study of the fundamental causes of brittle fracture. Their paper, "Evaluation of Weld Joint Flaws and Reinitiating Points of Brittle Fracture – Part II", emphasizes: (a) residual and reaction stresses can be an important part of the total stress required to initiate a fracture, and (*b*) the greater the residual and reaction stresses, the lower the nominal stress required to initiate the fracture. The length of the flaw appears to have little influence on the stress required to initiate a brittle fracture. Stresses applied to the area of the flaw front were sufficient to cause the initiation of brittle fracture at low nominal stresses.

Working conditions were simulated as much as possible in this study. For example, reaction stresses were applied by a mechanical mechanism similar to that used in jacking plates in place during fabrication of ships. These stresses caused brittle failure at one half of the yield strength of the steel tested. The flaw specimens were evaluated by welding the specimen containing the flaw as a patch in the wall of a sphere. The temperature of the sphere containing the patch was lowered below the transition temperature of the steel. After the desired temperature was reached, the sphere was loaded hydrostatically. The testing facility was not capable of producing sufficient stress to initiate brittle fracture from flaws less than 2 in. in length. The authors report that it is quite difficult to initiate brittle fracture in flaws less than 4 in. in length.

(Continued on p. 172)

Book Review

Cast Iron—How and Where to Use It

*Reviewed by HANS J. HEINE**

GRAY IRON CASTINGS HANDBOOK, Edited by Charles F. Walton, Gray Iron Founders' Society, Inc., Cleveland, 1958. 607 p. $10.

TWENTY-ONE YEARS AGO a monumental work by John Bolton became the standard compendium on gray iron. In the intervening years, although many technical reports have appeared dealing with his basic material, few books have appeared, and an up-to-date, comprehensive and authoritative reference book has been long overdue. The Gray Iron Castings Handbook now fills that need.

A number of noted metallurgists and research organizations have cooperated in either developing or gathering information for this book which, as the preface states, is designed to be of value primarily to engineering students, engineers, purchasing agents and management personnel who may not be fully aware of the usefulness of gray

*Technical Director, Publication Development Div., American Society for Metals, Cleveland.

and ductile iron castings. For the metallurgist and the designer, this volume is a valuable reference supplement.

The chapter on metallic and nonmetallic coatings is outstanding. It describes surface finishes applied to gray iron to meet appearance, corrosion, wear, and other special requirements. Sprayed and hot dipped coatings as well as hard facing materials are thoroughly discussed, and the state of the art of electrodeposition and cementation is explained and many typical examples are given. Cementation may be called a first cousin to hot dipping, with this difference, however: The use of molten metal is not required since the casting can be heated in a powdered metal, a gaseous atmosphere or a fused bath of metal salts. Secondly, the cementation reaction is actually a slow creeping of one metal into another. The process has been used successfully on meat mincer parts, pug-mill knives and augers.

The chapter on welding, joining and cutting opens with a statement designed to dispel the prejudice – long prevalent among designers until quite recently – against the use of gray iron in fabricated assemblies. Production welding of gray iron pipe to a gray iron casting using gray iron filler rod (high in carbon and silicon since the heat of the torch will burn out a portion of these elements) is not uncommon today. Moreover, with nickel-base electrodes gray iron can be welded to dissimilar metals such as carbon steel, stainless steel, and Monel. Gas burners for home heating, for instance, consist of a gray iron-steel assembly arc welded with a nickel electrode.

Improved joining techniques, notably in braze welding with bronze and nickel filler material and brazing with silver alloys, have extended the range of materials that can be fabricated. The section is quite practical. A major portion of it describes repair welding of castings.

The part on heat treatment reads like an apotheosis of Jim Vanick's statement made many years ago: "Heat treatment of gray iron is a vast uncultivated field held in reserve for future expansion . . ." Much data, especially on flame hardening, are comprehensively presented for the first time, and line drawings help the reader to visualize the different processes in use.

The chapter on properties is separated into two parts, one dealing with gray and the other with nodular iron. It puts the ductile member of the gray iron family in sharper focus. The first section discusses the significant engineering properties of the plain (unalloyed) and low-alloy (generally containing less than 3% of Cr, Cu, Mo, Ni and V) gray irons. It is refreshing to see not a rehash of data that have been carried in handbooks for generations, but a new approach and an intelligent attempt to winnow the chaff from the wheat. The second section contains a factual account of the properties of nodular iron, particularly those properties that recommend it as a useful engineering material. Especially valuable are the Jominy end quench hardenability curves showing the effect of carbon and manganese on the hardenability of a series of ductile irons. The reader is almost overwhelmed by authoritative tabular data on impact strength, endurance limit, elevated-temperature properties and dimensional stability. A series of graphs depicts creep and stress-rupture data. It is clearly indicated that the pearlitic structure is superior to the ferritic structure up to about 800° F. and that a ferritic ductile iron containing 0.81% Mo has a creep strength of 27,000 psi. at 800° F.

The section relating to specifying and purchasing includes not only basic standard specification data, but also provides a survey of the different casting processes in commercial use today and describes the capabilities of the industry. The illustrations, clear, simple and devoid of unnecessary detail, are a helpful supplement. The line drawings showing a simple two-piece pattern with a flat parting, mounted to make a match plate, are typical. The composition of core boxes and sweep patterns is also explained with the aid of illustrations.

Additional chapters cover the history of the gray iron industry, advantages of iron castings, and design considerations. A valuable and helpful feature is the glossary of terms near the end of the book – semantics so often being the stumbling block to a proper understanding of technical language. An appendix describes the fundamentals of heat treatment.

It seems almost a must for reviewers to have at least one complaint; in fact, some apparently spend their best efforts in this direction. (The psychologists would probably explain the phenomenon by saying that reviewers are nothing but a breed of frustrated authors out in the cold.) The only shortcoming this reviewer sees is in the index, which could be more extensive, thereby increasing the value of the handbook as a reference work. A future edition could easily remedy this situation.

Correspondence . . .

Dislocation Model

PROVIDENCE, R. I.

The recent article by Guy and Criswell presenting an analogy of a dislocation by means of two rows of magnets (*Metal Progress,* June 1957, p. 82) inspired the model shown here. The forces between atoms are represented by forces between poles of opposite signs of cylindrical magnets. The magnets are mounted on flexible springs allowing them to deflect in a vertical plane parallel to the rows.

Figure 1 shows the unstressed equilibrium position of the magnets. As the bottom row is displaced, a dislocation is introduced from the left edge (Fig. 2). It travels toward the right edge (Fig. 3) and the model is left in a deformed condition after the dislocation has moved the entire length of the row (Fig. 4).

Slip, in this model, always occurs by travel of a dislocation as long as the deformation is applied slowly.

J. GURLAND
Associate Professor of Engineering
Brown University

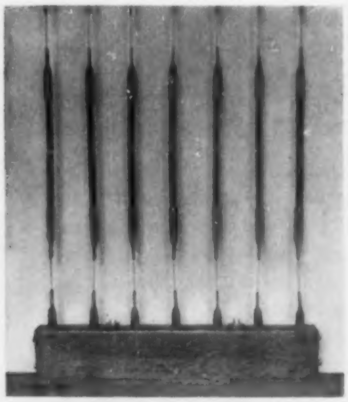


Fig. 1 – Unstressed Equilibrium Position of Magnets

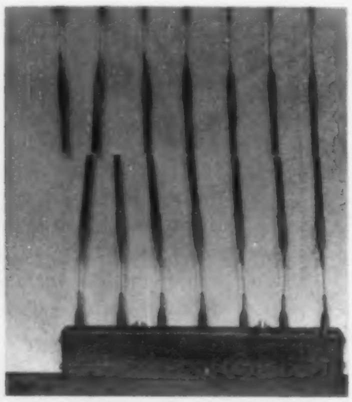


Fig. 2 – Bottom Row Is Displaced (Dislocation Introduced)

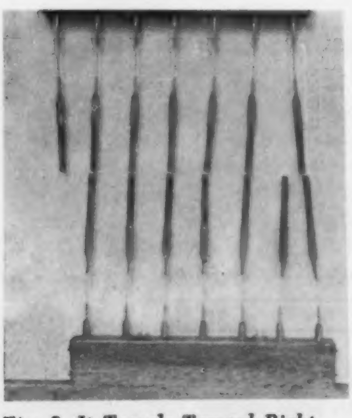


Fig. 3–It Travels Toward Right

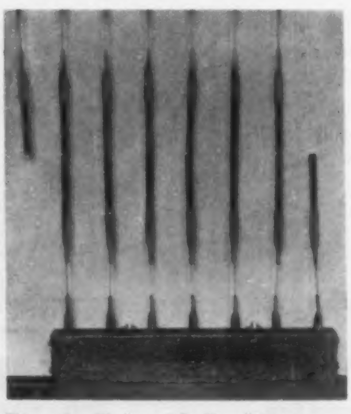


Fig. 4 – Deformed Condition

The Windscale Incident (Wigner Energy Release)

LONDON, ENGLAND

Your issue of January this year contained my short article on the Windscale incident (p. 114), an accident which occurred at a British plutonium-producing pile during a shutdown for "Wigner release." Investigations have since been carried out by British scientists on other methods for release of stored energy from reactors, and in March Harwell engineers made a successful release by a new technique on BEPO (British Experimental Pile, which is an air-cooled, graphite-moderated reactor of the same type as Windscale).

The inlet air flow to the reactor was reduced to about 5% of full normal flow and was heated by 750 kw. of heating grids installed in the inlet duct. This gradually heated the air entering the reactor to 130° C. The graphite structure was thereby heated up slowly over a period of 10 hr. to about 90° C. At this point, a slow release of stored energy began and the temperature of the graphite rose, reaching a maximum of 330° C. During this period, some blocks of the graphite were seen to rise sharply in temperature by about 200° C. in a short time – of the order of 5 min. The zone in

Windscale . . .

which the stored energy release was taking place spread slowly from the air inlet end of the reactor to the exit end and to other radial regions. The whole operation was controlled by a battery of 74 recorders, and a staff of 75 engineers and scientists was engaged.

The reactor could at any time have been blown cold by turning on the main circulating fans. This work confirms, therefore, that a Wigner energy release can be carried out with complete safety when it is fully instrumented.

T. Bishop
John Miles & Partners
(London) Ltd.

Colleges Need Money From Industry

Golden, Colo.

The above heading in April *Metal Progress* is all too true. As president of a sister institution to Case (a privately endowed college), I can say that its problem is so similar to that of the tax-supported Colorado School of Mines that it reflects the problem faced by all engineering schools in America.

Undoubtedly, industry needs more engineers – metallurgists as well as civils, mechanicals, and all the others. Industry proves this statement year after year by sending a flock of personnel men to the campuses to interview the men in the graduating class. Where can industry get these needed men, now lacking?

One possibility is that new institutes could be built. This would be very costly. To duplicate the plant at Colorado School of Mines would cost at least \$20,000,000. To endow its operation (costing \$2,000,000 annually) would require \$50,000,000. The total is \$70,000,000. The product would be 200 engineers annually; their cost (4% of 70,000,000 divided by 200) would be \$14,000 each.

Another possibility is that large industrial organizations take over the job themselves. Even if the product were engineers rather than technologists, the cost would not be much if any less than the above.

The third and by all odds the best

Colleges . . .

plan is to strengthen the existing engineering colleges and institutes by generous financial support. This takes advantage of existing facilities and faculties. It is the most efficient and least costly solution.

How can an individual, a firm or an industry invest in engineering education most effectively? There are several things, I think, that should be kept in mind:

First, invest your money in the institutions which are directly serving your industry.

Second, invest your money where it will do the most good, namely in *faculty* rather than in facilities.

Third, consult the college management to find out where your investment would yield the greatest return.

Fourth, if you have funds for scholarships, split the money three ways, giving one third to the student, two thirds to the school.

Finally (if not too visionary), give the best engineers on your staff "sabbaticals," wherein they can join an engineering faculty for the year. The services of a good man invested in this way will result in many more good men in the future.

John W. Vanderwilt
President
Colorado School of Mines

High-Temperature Report Available

Washington, D. C.

The article on "Improvement in High-Temperature Alloys by Boron and Zirconium", by W. J. Pennington, in the March issue, p. 82, makes reference to a University of Michigan report (No. 55, January 1957) to the N.A.C.A. Your readers may be interested in knowing that this report was made available to the public in June 1957 as N.A.C.A. Technical Note 4049, "Influence of Crucible Materials on the High-Temperature Properties of a Vacuum-Melted Ni-Cr-Co Alloy", by R. F. Decker, J. P. Rowe and J. W. Freeman.

N.A.C.A. Technical Notes are available without charge upon application to the Division of Research

Report . . .

Information, National Advisory Committee for Aeronautics, 1512 H St., N. W., Washington 25, D. C.

BERTRAM A. MULCAHY
Chief, Division of Research Information
N.A.C.A.

Macro-Etching for Quality Control

BRANFORD, CONN.

I enjoyed reading Mr. Rutherford's article "Thirty Years in American Metallurgy", in the February issue of *Metal Progress.* Under the heading "Quality Control", I am afraid Mr. Rutherford has overlooked a testing method which has contributed tremendously to the quality of iron and steel within the last 30 years or so – namely macro-etching. The part played by macro-etching in the production of sounder tool and constructional steels, castings and forgings cannot be overemphasized. In fact, its application to quality control has been so effective that it is now being used extensively in both the ferrous and nonferrous industries.

HENRY G. KESHIAN
Consulting Metallurgist

Fuel Elements for Economical Atomic Power

LEMONT, ILL.

Readers of *Metal Progress* have no doubt read, either in newspapers, magazines of opinion, or in technical periodicals, contrasting opinions as to the necessity for building atomic power plants competitive with those now existing and which burn carbonaceous fuels. Without entering into any argument about how this might be done – nor, in fact, whether it should be done on a "crash basis" – I might suggest that the problem for the immediate future is posed less by our own economic situation than by international considerations, which takes it out of the realm of engineering and science and into the realm of politics.

I would like to emphasize, however, that there is one area in which

Lithium alloys for thrifty metal makers

The wonderful thing about these *property-boosting* lithium alloys is that they call for so little lithium. In many cases, the addition of a few ounces is all that's needed to tip the scales toward . . . more desirable physical properties, better grain structure, improved cold working characteristics, and many other features. Needless to say, the addition of lithium can't improve *every* alloy. But where it does, its cost is infinitesimal compared to the advantages it gives. Just look over the few examples given here. You'll find that lithium is an alloying metal well worth investigating.

To find out more about lithium metal (99.9% pure) and what it might do for you, write for Bulletin 101. Address letterhead request to Technical Literature Department, Foote Mineral Company. 424 Eighteen West Chelten Building, Philadelphia 44, Pennsylvania.

Magnesium-Manganese-Lithium

[illegible]-98% MAGNESIUM
1-10% MANGANESE
1-10% LITHIUM

As little as 1-10% lithium in the above alloy gives greatly improved cold working properties. As cast, this alloy can be cold worked to 60% reduction; after annealing, it can be cold worked to 95% reduction.

Zinc-Lithium

96.5-99.8+ % ZINC
.1-2% MANGANESE
.05-1% NICKEL
.005-.5% LITHIUM

The percentage of lithium used to refine the grain structure of this zinc alloy works out to as little as 1 pound of lithium to every 1000 tons of zinc. This amounts to about 1¢ per ton!

Aluminum-Lithium

84.15% ALUMINUM	.75% MANGANESE	.1% LITHIUM
12% ZINC	.5% IRON	
2% COPPER	.5% SILICON	

The physical properties of this aluminum alloy are reported to be superior to the better known, high-strength aluminum alloys. The presence of the lithium improves its physical properties and correspondingly decreases its density.

FOOTE MINERAL COMPANY

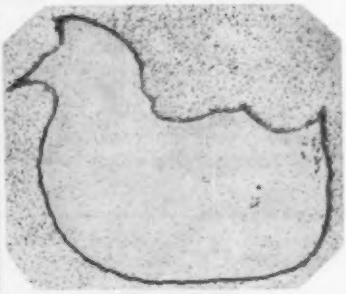
LITHIUM METAL, CHEMICALS, MINERALS • ELECTROLYTIC MANGANESE METAL • NITRELMANG • HYDROGEN-REMOVED ELECTROMANGANESE • RIMEX MANGANESE SULPHIDE • WELDING GRADE FERRO ALLOYS • COMMERCIAL MINERALS AND ORES • ZIRCONIUM, TITANIUM, HAFNIUM (IODIDE PROCESS)

Fuel Elements . . .

a speed-up could undoubtedly be achieved. It falls not in the design and construction of different or bigger reactors but in a much intensified program of fuel element fabrication and processing. Simple, cheap fuel elements and processing methods can reduce costs significantly and probably swiftly. The present reactor design and construction program of the U.S. Atomic Energy Commission should determine the likeliest reactor systems, but they will not necessarily or rapidly produce information about manufacture of cores and reprocessing fuels. Such a program on fuel elements can be carried on independently of any particular reactor design. It would require a significant expansion of basic and fabrication metallurgy, of the irradiation facilities available for fuel testing and finally of the chemical engineering process studies necessary in connection with the new fuel element designs.

NORMAN HILBERRY
Director
Argonne National Laboratory

A Sitting Duck



NEWARK, N.J.

Heating in metallic units can be obtained by either conduction or induction. Metallographic examination of a sample of Tophet A (80% nickel, 20% chromium) etched in Marbles' reagent does not differentiate between con-duck-tion or in-duck-tion. Maybe some duck hunters among the A.S.M. can give the answer.

WILLIAM A. GRONINGER,
Metallographer
Wilbur B. Driver Co.

Personal Mention

Charles M. Beeghly

CHARLES M. BEEGHLY ⊕, a director of Jones & Laughlin Steel Corp., Pittsburgh, has been elected executive vice-president of the company. He became vice-president of Jones & Laughlin's new Strip Steel Div., when that division was established last August to operate the recently acquired Cold Metal Products Co. in Youngstown, Ohio. Mr. Beeghly had been associated with Cold Metal for 24 years before its merger with Jones & Laughlin.

A native of Ohio, he studied at Ohio Wesleyan University and after graduation in 1930, gained experience in the steel industry in several plants in the East until joining Cold Metal as a salesman. Rising to production manager in three years, he went on to serve as sales manager and general manager; he was called into the armed service in 1942. Discharged as a major in the Air Force in 1945, he returned to Cold Metal and the following year was named vice-president and director of the company.

An active ASMember, he also holds memberships in the American Iron and Steel Institute and the American Ordnance Association.

Donald W. Johnson ⊕ has been named manager of Reynolds Metals Co. aluminum reduction plant in Longview, Wash. Mr. Johnson was transferred to Longview last August from the Reynolds Troutdale, Ore., reduction plant where he served as assistant plant manager.

Harlan W. Diefendorf ⊕ has been appointed superintendent of melting at Crucible Steel Co. of America's Sanderson-Halcomb Works in Syracuse, N. Y. Since joining Crucible in 1949, he has held various positions in the metallurgical department and until his recent promotion was assistant superintendent of melting.

Francis X. Maher ⊕ was recently named district sales manager for the north central area, of NRC Equipment Corp., Newton, Mass., directing sales and engineering service in Ohio and neighboring states from the company's Cleveland office. Prior to his appointment, Mr. Maher was a sales engineer for the firm.

Bruno Sachs ⊕ has been elected to the board of directors of Tenney Engineering, Inc., Union, N. J. Dr. Sachs is vice-president in charge of engineering and manufacturing for Tenney and in addition is currently serving as a lecturer in mechanical engineering at the evening division of the College of the City of New York.

Maurice F. Hasler ⊕ received the fourth annual Beckman Award for an outstanding contribution to the field of chemical instrumentation at the national meeting of the American Chemical Society in San Francisco recently. The $1000 award is sponsored by Beckman Instruments, Inc., of Fullerton, Calif., and is designed to honor pioneering achievements in this field. Dr. Hasler, president and director of research for Applied Research Laboratories, Glendale, Calif., was awarded this honor for his development of a direct-reading optical emission spectrometer which gives a complete chemical analysis of a metal in 1 min.

Clyde Williams ⊕, former president of Battelle Memorial Institute and now president of Clyde Williams and Co., will present the 6th Gillett Memorial Lecture at the annual meeting of the American Society for Testing Materials on June 24 in Boston, speaking on "High-Temperature Metals – Their Role in the Technological Future".

George Angeletti ⊕ recently accepted a post as senior sales engineer in beryllium-copper alloys with the Brush Beryllium Co., Cleveland.

E. D. Weisert ⊕ and **R. A. Perkins** ⊕ have been advanced to positions as technical supervisors at the Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N. Y. Mr. Weisert, named technical supervisor–materials application, was a section leader in the corrosion section of the metals research group before taking on his new assignment. Now technical supervisor – metals engineering, Mr. Perkins was formerly senior research assistant in the stainless steel department.

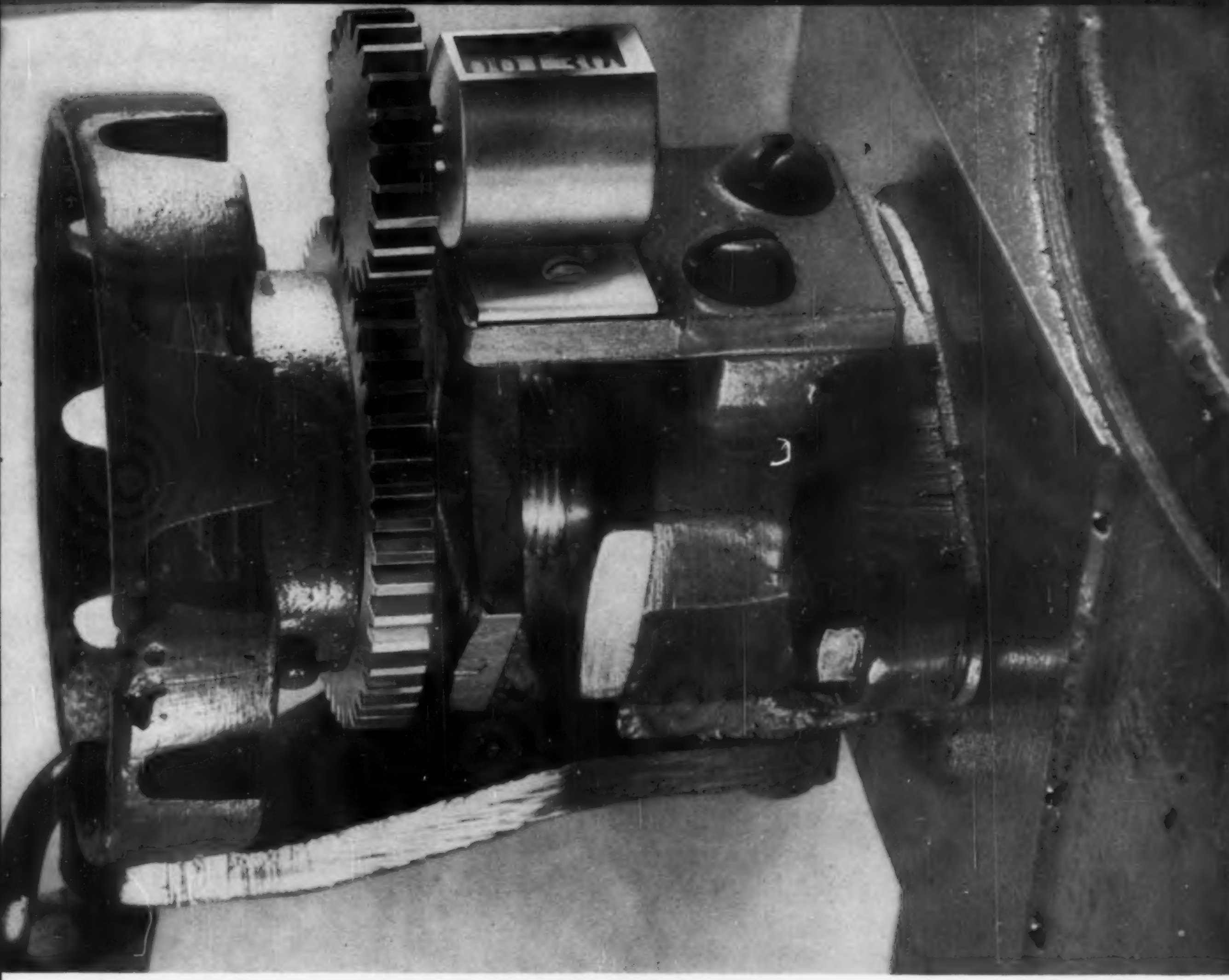
John R. Vreeland ⊕ has been appointed special consultant, heat exchanger sales, for Chase Brass & Copper Co., Waterbury Conn., a subsidiary of Kennecott Copper Corp. Mr. Vreeland has been affiliated with Chase for nearly 30 years and for the past year and a half has been staff manager of sheet and strip sales.

R. E. Orton ⊕ is now assistant general manager of Cleveland Trencher Co., Cleveland.

Robert Alan Huggins ⊕ has been selected to receive the Robert Lansing Hardy Gold Medal for 1958 of the American Institute of Mining, Metallurgical, and Petroleum Engineers. The award is given to a young metallurgist, under thirty years of age, in recognition of exceptional promise rather than achievement. Dr. Huggins is assistant professor of metallurgy at Stanford University, where he has been teaching since 1954.

William Keightley Croll, Jr., ⊕ formerly a student metallurgist at the Colorado School of Mines, has accepted a post as research metallurgist at Battelle Memorial Institute, Columbus, Ohio.

Don Beggs ⊕ and **O. E. Cullen** ⊕ have been promoted to managerial positions by Surface Combustion Corp., Toledo, Ohio. Mr. Beggs is now manager of engineering in the furnace division, while Mr. Cullen's new position is manager of research in the development department. At the same time, **J. Montagino** ⊕ was named chief engineer in the special heat treat division.



Air-gas Ratio Valve

Twin installation of Model 6-MR Atmos Gas Generators deliver up to 6,000 cfh at Thomas Strip division of Pittsburgh Steel. Increased equipment capacity, reduced labor costs, and closer control make Kemp units money savers in every installation.

Kemp Convection Dryers

Kemp Immersion Melting Pots

Kemp Industrial Carburetors

Kemp Orlad Dryers

Personals . . .

Paul Yavorsky has joined the Zirconium Corp. of America, Solon, Ohio, a subsidiary of Oliver Tyrone Corp., as technical director. He has been associated with the high-temperature ceramic industry since 1939, most recently as chief ceramic engineer for McDanel Refractory Porcelain Co., Beaver Falls, Pa.

Eugene S. Machlin, on sabbatical leave from his position as associate professor of metallurgy at Columbia University, is acting director of research for the Utica Metals Div., Kelsey-Hayes Co., Utica, N. Y.

T. F. Olt, director of research of Armco Steel Corp., Middletown, Ohio, has been elected vice-president – research. Mr. Olt, who has been with the company nearly 30 years, has held various supervisory positions in the research division; he was director of research for the past 11 years. At the same time, **K. P. Campbell** has been promoted to manager of the Houston, Tex., plant of Armco's Sheffield Div. Mr. Campbell joined the Kansas City plant of Sheffield in 1928 and was transferred to the Houston plant as works metallurgist in 1942. For the past year he had served as general superintendent – operations.

John M. Stokely has been promoted from supervising research engineer to division supervisor of the greases and industrial lubricants division of the Richmond Laboratory of California Research Corp., Richmond, Calif. Before coming to California Research, he was a metallurgist for the Richmond refinery of Standard Oil of Calif.

Gerald J. Grott, chief metallurgist of Michigan-Standard Alloy Casting Co., Detroit, has been awarded the Gustav A. Lillieqvist *Steel Foundry Facts* Award by the Steel Founders' Society of America. This award is presented annually for the best article in *Steel Foundry Facts*.

F. Troy Cope, Jr., an employee of the Electric Furnace Co., Salem, Ohio, for over 20 years, has been named vice-president in charge of sales. He has been a director of the company since 1952.

Personals . . .

Gerhard Derge, Jones & Laughlin Professor of Metallurgy at Carnegie Institute of Technology, has been appointed editor of the *Transactions* of the Metallurgical Society of A.I.M.E. Professor Derge will serve as editor in addition to his regular work at Carnegie Tech. He has been on the faculty there since 1934, except for a period during the Second World War when he was assigned to the Manhattan Project of the University of Chicago and to Oak Ridge National Laboratory.

William R. Johnson has been appointed assistant director of research and development for Associated Spring Corp., Bristol, Conn. Mr. Johnson was formerly chief research metallurgist at the company's research center in Bristol and before that was research metallurgist at the Wallace Barnes Co., a division of Associated Spring Corp., in Bristol.

William P. Lewis has joined the sales staff of Hamler Industries, Inc., Chicago, and will be in charge of the company's Detroit office. He was formerly a sales representative for Ex-Cell-O Corp., Detroit.

Raymond D. Daniels has become a member of the metallurgical engineering school faculty of the University of Oklahoma. Daniels received his bachelor's, master's and doctor's degrees from Case Institute of Technology and served as a research assistant there. More recently he was a physicist with the National Bureau of Standards.

C. Wesley Murray has been appointed manager of knife sales for the Heppenstall Co., Pittsburgh. He joined the company in 1935 and has been a member of the Pittsburgh sales department since 1953.

E. J. Wilson, Jr., has been appointed chief welding research engineer with the Graver Tank & Mfg. Co., Inc., East Chicago, Ind. He was formerly associated with the Oak Ridge National Laboratory and Westinghouse Electric Corp.

Fred Hunter has resigned as general manager of a commercial heat treating firm in Syracuse, N. Y., to form his own company, Steel Treaters, Inc., Oriskany, N. Y., where he serves as president.

Personals . . .

W. F. Borgerd, after 40 years of engineering service for the International Harvester Co., has retired as manager of research engineering. During his years with International Harvester, he has served in various supervisory positions including divisional chief engineer and manager of engineering.

J. F. B. Jackson has been appointed managing director of the board of A.P.V.-Paramount Ltd., Crawly, Sussex, England; he has also joined the board of P. I. Castings (Altrincham) Ltd., Altrincham, Cheshire, England. Mr. Jackson became a member of the A.P.V.-Paramount board in 1954 following five years as director of the British Steel Castings Research Assoc.

Harry O. Walp, Jr., has been named product manager for vacuum heat treating furnaces for the vacuum equipment division of F. J. Stokes Corp., Philadelphia. Since joining the company in 1952, Mr. Walp has gained field sales experience in the New York, Philadelphia and New England territories of the company.

James A. Glunt has been named chief metallurgist of the Alan Wood Steel Co., Conshohocken, Pa. Prior to joining Alan Wood, he was assistant chief metallurgist in the Cleveland Works Div., Jones & Laughlin Steel Corp.

R. W. Joseph and **L. J. Trilli**, metallurgist and supervising metallurgist, respectively, of the openhearth and blooming mill division, Inland Steel Co., East Chicago, Ind., have received the F. B. McKune Memorial Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers for the best paper on openhearth practice submitted to the Openhearth Conference held in Cleveland in April. The runner-up paper, submitted by **R. E. Stoll**, general supervisor, research and development, and **E. C. Rudolphy**, chief development metallurgist, South Works, U. S. steel Corp., Chicago., was awarded the Openhearth Conference Award.

Sed Dye is now employed as sales engineer by Sterling Steel Casting Co., East St. Louis, Ill.

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Save Money
Save Trouble

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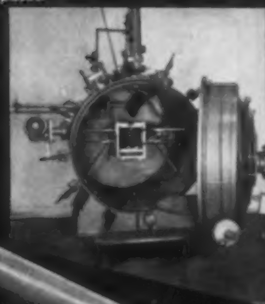

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Personals . . .

Donald M. Forney, Jr., recently assumed the duties of senior project engineer of the creep rupture and fatigue section metals branch, materials laboratory of the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Before accepting this assignment, he was a test engineer in the engineering test laboratories structures group of Convair Div., General Dynamics Corp., San Diego, Calif.

Stanley D. Whiteside has been appointed staff engineer for Lindberg Industrial Corp., Chicago. Before joining Lindberg, Mr. Whiteside was general sales manager of the industrial furnace and oven division of W. S. Rockwell Corp., Fairfield, Conn., for 14 years.

A. Clyde Willhelm, Jr. has left his position as plant metallurgist for International Silver Co., Wallingford, Conn., where he was concerned with hot forged jet engine parts, to become a metallurgist in the materials and processes section of Hayes Aircraft Corp., Birmingham, Ala.

J. R. Eckley is now sales representative for Saxonburg Ceramics, Saxonburg, Pa., and Sauereisen Cements Co., Pittsburgh.

Willard B. Pratt, formerly vice-president of Bonded Diamond Products of Worcester, Inc, is now president of Vanguard Abrasive Corp., Le Roy, N. Y.

William A. Reich has been named manager of the engineering section of the General Electric Co. metallurgical products department in Detroit. Since joining G. E.'s research laboratory in 1938, Mr. Reich has served as head of the metallurgical laboratory at the Schenectady, N. Y., works, and more recently as manager of advanced engineering in the metallurgical products department (formerly Carboloy Dept.) in Detroit.

Robert O. Offill has accepted a position as advisory engineer for Lindberg Industrial Corp., Chicago, Ill. For 10 years Mr. Offill was sales manager of the Midwest-Southwest regions of the industrial heating division of Westinghouse Electric Corp., and prior to that was affiliated with Carnegie-Illinois Steel Co.

Metals Engineering Digest

. . . Interpretive Reports of World-wide Developments

Uncommon Metals Ready to Solve Difficult Problems

Digest of "Uncommon Engineering Metals", by J. P. Denny and L. F. Kendall, Jr., General Electric Co., Schenectady, N. Y. Presented before the Design Engineering Conference, Chicago, April 15, 1958. The paper was contributed by the Machine Design Div. of A.S.M.E.

Mechanical Properties of Some Uncommon Metals

Metal and Test Temperature	Tensile Strength, Psi.	Yield Strength (0.2% Offset)	Elongation, %
Zirconium			
Pure, annealed, room	34,000	10,000	47
Commercial, annealed, room	50,000	35,000	35
Commercial, 40% cold worked, room	80,000	70,000	13
Zircaloy 2			
Annealed, room	68,000	45,000	22
Annealed, 500° F.	32,000	18,000	36
Hot rolled, room	82,000	66,000	42
40% cold worked, room	108,000	99,000	36
Hafnium			
Pure, annealed, room	59,000	22,000	35
Pure, annealed, 500° F.	38,000	12,000	51
Pure, hot rolled, room	79,000	63,000	15
Vanadium			
Commercial, annealed	70,000	63,000	32
Commercial, hot rolled, room	91,000	—	22
Commercial, hot rolled, 1112° F.	40,000	—	38
Commercial, hot rolled, 1832° F.	7,000	—	50
Columbium			
Commercial, room	39,000	24,000*	49
Commercial, 1022° F.	32,000	10,500*	24
Tantalum			
Commercial			
Sheet, annealed, room	50,000	—	40
Sheet, worked, room	110,000	—	1
Wire, annealed, room	100,000	—	11
Wire, worked, room	180,000	—	1.5
Chromium			
Pure, annealed, 626° F.	41,000	27,000	14
Pure, annealed, 1965° F.	9,000	9,000	104
Rhenium			
Pure, annealed, room	164,000	135,000	28
Pure, worked, room	322,000	311,000	2
Pure, worked, 1850° F.	124,000	—	1
Pure, worked, 2700° F.	40,000	—	1

*Proportional limit.

Faced with increasingly stringent environmental requirements, materials' engineers are finding that metals formerly dismissed as unthinkable now merit serious consideration. Seven metals which are in this picture are zirconium, hafnium, vanadium, columbium, tantalum, chromium, and rhenium. All are available, in at least development quantities.

Zirconium – Its outstanding property is its corrosion resistance. Mediums in which it is especially useful include hydrochloric, nitric, sulfuric, and phosphoric acids, hydrogen peroxide, most chlorides, and most organic acids. In this respect, it is comparable to titanium, tantalum, stellite, the Hastelloys, and stainless steels. For some applications, zirconium is markedly better than any of these since it is resistant to both alkaline and acid mediums.

Zirconium has a lower density than stainless steel; its thermal conductivity is about the same. Although zirconium is moderately strong at room temperature, the strength drops rather sharply at elevated temperatures. As the data in the table indicate, alloying counteracts this tendency to a considerable extent. At temperatures above about 900° F. zirconium and its alloys must be protected from prolonged exposure to CO, CO_2, SO_2, steam, hydrogen, and flue gases.

Zirconium and its alloys can be fabricated by techniques used for stainless steels and titanium. Hot working operations must be done in protective sheaths or atmospheres except for heavy sections such as ingots and thick plate. In addition to forging, rolling, swaging, drawing,

Uncommon Metals . . .

and forming, extrusion is useful for producing pipe, tubing, and complex shapes. Zirconium can be joined by welding under an inert shield or silver brazing in vacuum. With sharp, carbide-tipped tools, it is easily machined.

Industrial applications of zirconium depend on its unusual properties. Its use in boiling-water and pressurized-water reactors seems assured for the foreseeable future, since its nuclear properties and corrosion resistance make it nearly ideal for these applications.

Lower prices will increase the use of zirconium for chemical processing equipment and related applications where corrosion problems are severe. Among the devices which have been fabricated of zirconium are heat exchangers, valves, reaction vessels, agitators, fan blades, and steam ejectors for use with hydrochloric acid. Other applications include alloys, especially with magnesium as a deoxidant in steels; getters to remove traces of gaseous contaminants from electron tubes; seals of glass and ceramics to metal; pyrophorics such as flash bulbs, fireworks, and primers for explosives. Potential uses include electrolytic capacitors and rectifiers in place of presently used tantalum, surgical devices for use in the human body, and for hard, corrosion resistant fountain pen tips.

Hafnium – This metal (present price about \$70 per lb.) has become available in practical quantities as a result of the atomic energy program to produce zirconium. In general, hafnium has the properties of zirconium; the most important exception to this is the absorption of thermal neutrons. Pure zirconium absorbs very few neutrons so that it is useful for structural components in reactors. Hafnium has an unusually high absorption and is useful for controlling reactors by absorbing excess neutrons. Hafnium also has a higher melting point than zirconium, a much higher allotropic transition temperature, and nearly twice the density. Like zirconium, hafnium is unusually resistant to many corrosive fluids but is attacked by air and other gases at elevated temperatures.

When uncontaminated by nitrogen or oxygen, hafnium can be fabricated with nearly the same techniques used for zirconium. It has been forged, rolled, extruded, drawn, machined, and welded successfully.

In addition to its use for control of nuclear reactors, hafnium should find application where the corrosion resistance of zirconium and a higher transformation temperature are needed.

Vanadium – In button form this metal sells for about \$65 per lb.; in the form of lumps it's some \$50 per lb. In the hot rolled and annealed condition, vanadium has a pronounced yield point, and its stress-strain curve accordingly resembles that of mild steel. Its density is 0.22 lb. per cu.in. and its modulus of elasticity is 18-19 $\times 10^6$ psi. This interesting combination of properties suggests possible future structural applications.

From the corrosion standpoint, vanadium is resistant to alkaline

Uncommon Metals . . .

and hydrochloric-acid solutions, but is not attacked by the "water cycle" such as nitric. Its resistance to salt water may be classed as fair to good. There is evidence that it resists pitting by salt water but is subject to general corrosive attack. Its electrical resistivity at room temperature is 24.8 microhm-cm., a value higher than most of the common metals. It is a poor conductor of magnetic flux. Vanadium does not work harden rapidly, and may be cold worked readily. It is free cutting, and good machining results have been reported with tool characteristics similar to copper.

High-purity vanadium has been extensively investigated by the Atomic Energy Commission, but its value in atomic applications is uncertain. It is being used as a target in X-ray tubes, and its broader utility as an engineering material presents interesting possibilities. The relatively high electrical resistivity of the metal, combined with an intermediate density and modulus of elasticity, merits consideration.

Columbium – The availability of columbium (niobium) has changed from acute shortage to abundant supply. Powders and granules are being supplied by several manufacturers, and wrought forms are available on special order. Sheet, strip, foil, wire, rods, and other shapes can be produced by powder metallurgy or arc melting followed by cold working. Tubes may be made by forming and welding of strip. Pressed and sintered arc melting electrodes are also available. Powder costs, depending on quantity and purity, vary from $43 to $76 per lb.

The low thermal neutron capture cross section of columbium (1.2 barns) makes it attractive for nuclear applications; it is being used as the canning material for fuels in experimental reactors. It does not work harden rapidly and can be cold rolled and formed. It resists acids, although it is inferior to tantalum in this respect. The material has strength at 2200° F. comparable to pure molybdenum, and has an attractive density (0.31 lb. per cu.in.) in comparison to other refractory metals.

Columbium is embrittled by nitrogen, and this has hampered its ready

Tool Steel Topics

BETHLEHEM STEEL

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

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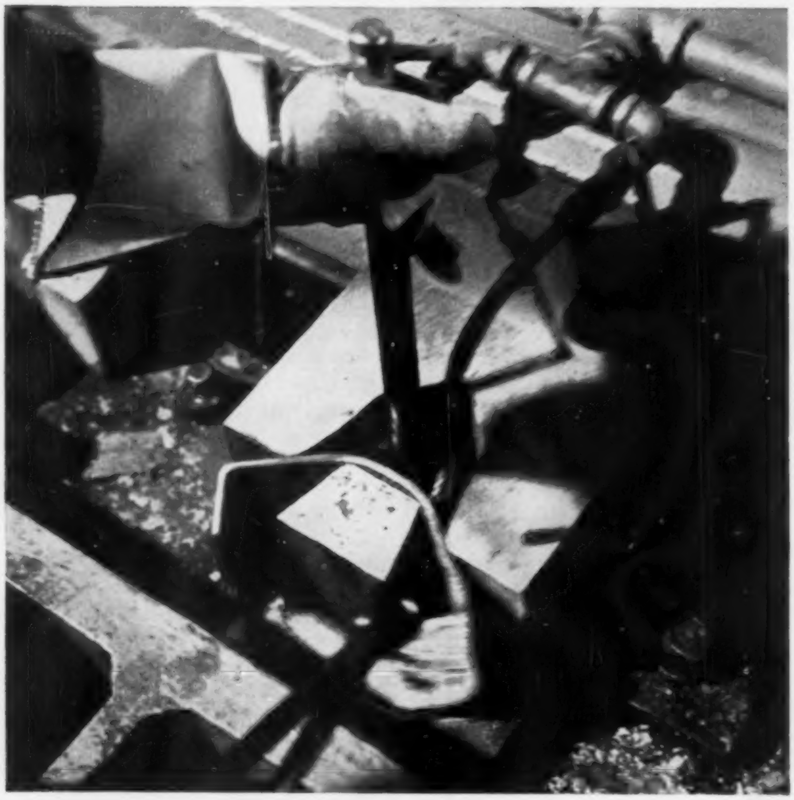

Highway Guard Rail Brackets Formed Red-Hot with Cromo-W

The product is a steel offset bracket, $\frac{1}{4}$ in. thick. It's used for fastening wire rope to highway guard rail posts. The bracket is formed red-hot, with a two-stage die of Bethlehem Cromo-W tool steel. Between 90,000 and 100,000 pieces are produced before redressing becomes necessary.

Cromo-W has a 5 pct chromium content and is one of our most popular general-purpose tool steels for a variety of hot-work applications. It offers good red-hardness and high shock-resistance. It also has good resistance to heat checking when cooled drastically during high-temperature operations, and is easy to machine and heat-treat.

Cromo-W is an ideal grade of tool steel for such diversified uses as die casting dies, bolt-gripper and bolt-header dies, trimmer dies, punches, and hot shear blades. In fact, it's a grade you can count on for long service in virtually any manufacturing operation involving severe shock and temperature change.

Typical Analysis

Carbon 0.35	Tungsten 1.55
Silicon 1.05	Molybdenum 1.65
Chromium 5.15	

In addition to Cromo-W, Bethlehem offers Cromo-WV and Cromo-High V for die casting and extrusion work. See your Bethlehem tool steel distributor for full details on these fine hot-work grades.

General view of the forming operation. Cromo-W is ideal for this hot-work application because of its good red-hardness and high shock-resistance.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Machining is a Tearing Operation

Close examination of the surface of a machined part, or chips machined from it, indicates the presence of countless minute tears. Generally, the tears can be seen most readily on parts machined at low speeds, with heavy feed and depth of cut. However, they are also present in all machined surfaces, even though not readily visible. The depth of surface tears on smooth machined tools and dies may be approximately one thousandth of an inch, or less. For this reason, the presence of the tears and their possible effects are often overlooked.

Most tools are heat treated after machining. Then they are ground all over to produce the exact dimensions, and to remove scale or decarburization resulting from the hardening operation. This procedure automatically removes tears in the surface previously produced during machining. However, many tools are ground only on certain portions, with the balance of the tool surfaces containing the remains of the machining tears, plus heat treatment scale and decarburization. This condition occurs often when you grind only the actual working surfaces which make contact with the parts. Tools produced by this method are more susceptible to failure in service because of stress concentration produced by the sharp change of section in the tears. This is particularly true of tools subjected to a large number of stress cycles in service, such as pneumatic tools.

Grinding all previously machined surfaces of tools after hardening is an operation which helps improve production from the tools. Grinding before hardening will also be effective, should grinding after hardening be inconvenient.

Uncommon Metals . . .

acceptance as a high-temperature structural metal. It is a superconductor at temperatures below 8 K., having the highest superconducting temperature of any known element with the exception of technicium (11.2 K.).

Most of the procedures for working and fabricating columbium are conventional. It has a tendency to gall during machining. Forming, bending, stamping, and deep drawing are done at room temperatures to avoid embrittlement resulting from reaction with gases at elevated temperatures. Columbium can be welded to itself by resistance and inert-arc methods.

Currently, there are no commercial uses for columbium except as an alloying agent. Experimental work is being directed towards developing columbium-base alloys for elevated-temperature structural applications and nuclear uses. Possibilities also exist for its use in electrolytic capacitors and in Cryotrons for computer application.

Tantalum – It is available in various forms, such as rod, sheet, wire, and foil. Tubing may be produced by welding on special order. The cost of tantalum powder varies from $46 to $60 per lb. depending on its purity. Fabricated forms are available at about $70 per lb.

Tantalum has exceptional resistance to corrosion by acids such as hydrochloric, nitric, sulphuric, and phosphoric. It forms anodic oxide films which have good stability below 300° C. (572° F.). It oxidizes readily above this temperature, however, and alloy development or protective coatings will be required for elevated-temperature service in air. It has a low vapor pressure at 2225° C., being superior to other refractory metals with two exceptions (rhenium and tungsten).

Tantalum may be welded to itself and certain other metals by resistance methods. Seam welding is usually done under water to prevent oxidation of the metal. Light welding pressures should be used, since heavy pressures lead to so little resistance across the joint that no weld is made. Tantalum also can be joined by inert-arc welding.

The metal can be annealed by heating in vacuum to above 1275° C.

(2327° F.), its recrystallization temperature. Cold forming is preferred because of its oxidation characteristics. In lathe operations, high cutting speeds using high-speed tools are recommended. Slow speeds will cause the metal to tear.

The most important uses for tantalum stem from its corrosion resistance. It is used in the chemical industries for handling chlorine, hydrochloric acid, chlorides, and nitric acid. Applications include heat exchangers, condensers, coils, and bayonet heaters. It is immune to body chemicals and has been used for a number of years for implants in the human body. Tantalum is used in electronic tubes, where its high melting point, low vapor pressure, gettering properties, and copious electron emission at reduced power levels are advantageous. Tantalum electrodes are used in electrolytic rectifiers, and tantalum sheet is being employed in capacitors. The oxide film which acts as the dielectric is formed on tantalum by anodic oxidation prior to assembly.

Chromium – The cost of chromium powder is $1.50 to $5.50 per lb., depending on purity and quantity. The primary deterrent to use of the metal in structural applications has been its room-temperature brittleness caused by nitrogen impurities. Carbon is also thought to have deleterious effects. The oxidation resistance of chromium is good at elevated temperatures but inferior to nickel-chromium alloys.

Because of its reactive nature, chromium must be melted in vacuum or in an inert atmosphere. The molten metal is usually superheated to obtain sufficient fluidity; casting temperature is about 2000° C. (3632° F.). Ingots are hot worked by extrusion, forging, and swaging. Sheaths are sometimes used to prevent contamination. Powder metallurgy processes also may be used for consolidation.

Development priority has been given to the production and properties of chromium, but only limited work has been done in joining, forming, and machining areas. It recently has been established that brittle cold worked chromium can often be made ductile by etching away the surface. This may be performed anodically

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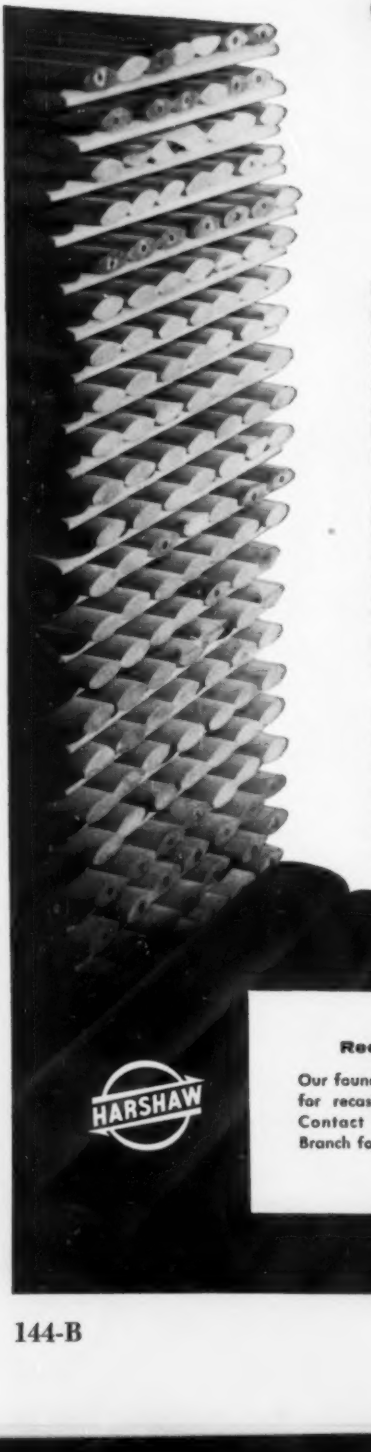

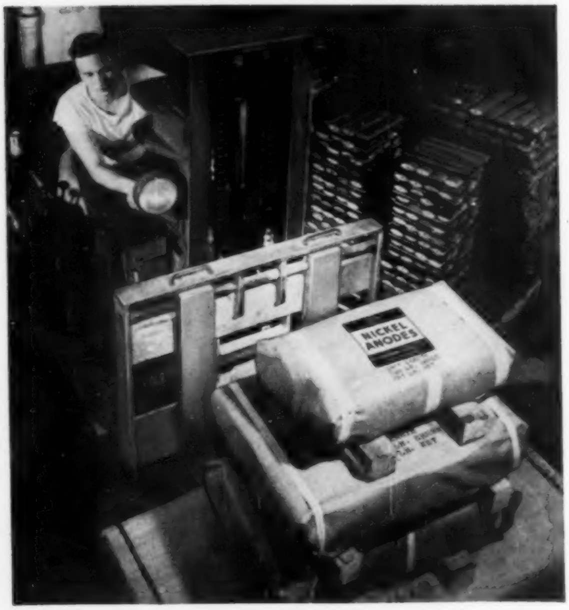

HARSHAW XXX CAST CARBON NICKEL ANODES are oval 1½" x 3" in cross section and are available in any length desired. Weight is approximately 1.1 lbs. per linear inch. They are normally used in dull, semi bright and bright nickel plating baths where the pH is 4.5 or lower.

HARSHAW ROLLED OVAL CARBONIZED NICKEL ANODES are 1¼" x 3" in cross section and are available in any length desired. Weight is approximately 1 lb. per linear inch. They are generally used in dull, semi bright and bright nickel plating baths where the pH is 4.5 or lower.

HARSHAW ROLLED OVAL DEPOLARIZED NICKEL ANODES have the same cross section and weight as tne rolled oval carbonized nickel anode and are also available in any length desired. These anodes are generally used in nickel plating baths where the pH is 4.0 or higher; they are extremely suitable for such use, as they will corrode well over a wide range of operating conditions.

PACKAGES

Harshaw anodes are wrapped in a fibre reinforced laminated (without asphalt) paper. They are protected from tramp oils, dirt and grease and remain clean until used. The possibility of such contaminents being introduced into the plating solution from anodes is thus kept to a minimum.

Harshaw anodes are shipped in compact packages which feature built-in skids and facilitate quick handling by mechanical or hand trucks. The packages stack easily and quickly. Also, no deposits or returnables are involved with this type of packaging.

Harshaw Nickel Anodes are readily available and prompt shipment of any quantity will be made upon receipt of your order.

Recasting Service

Our foundry facilities are available for recasting nickel anode scrap. Contact your nearest Harshaw Branch for further details.

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Uncommon Metals . . .

in a phosphoric acid-sulphuric acid bath or by direct immersion in hydrochloric acid solution. The effect is attributed to the removal of heavily nitrided surface layers formed during fabrication.

The potentialities of chromium and chromium-base alloys for structural application are not regarded as good at the present time. Work is continuing and a technical breakthrough is definitely within the realm of possibility. It is considered likely that the initial application of chromium-base alloys will be in other areas such as bearings, tool and die materials, where high hardness developed by surface reactions with nitrogen can be employed advantageously.

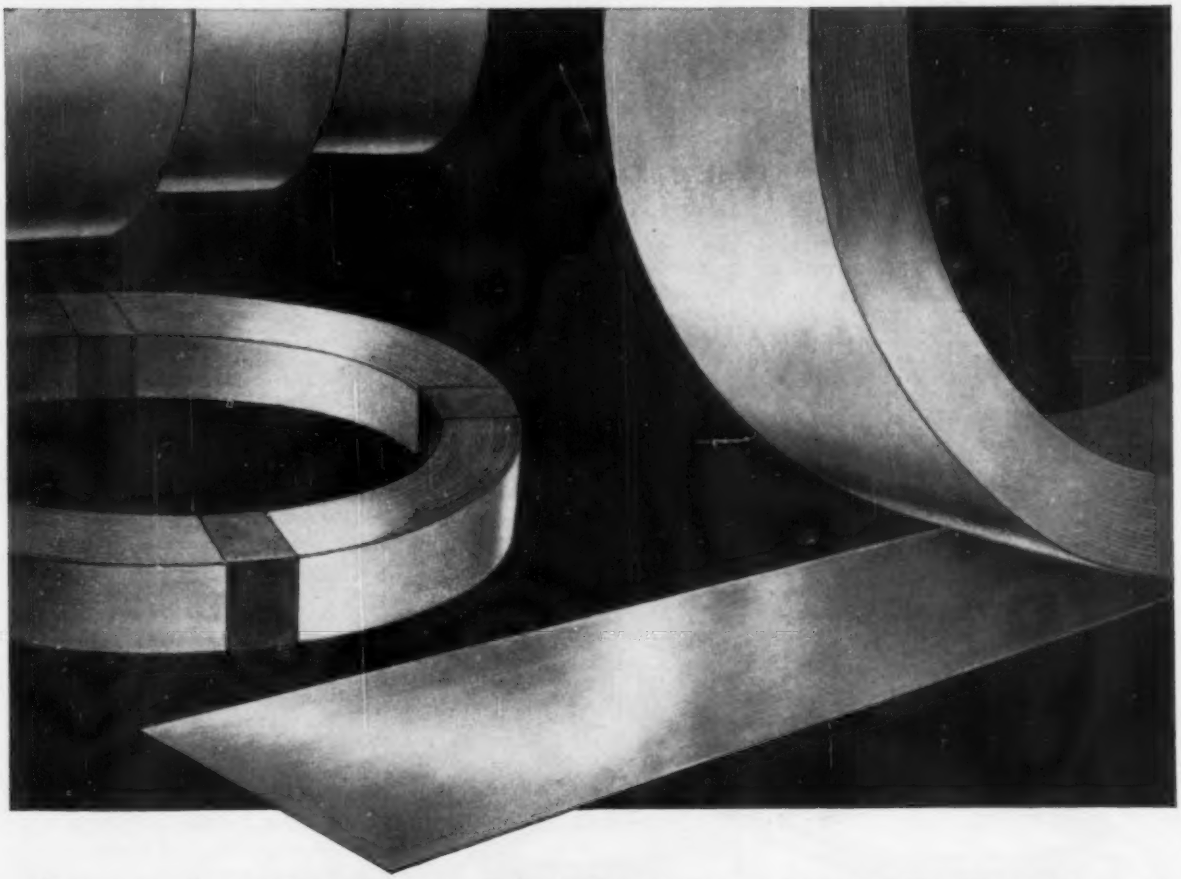
Rhenium – Its outstanding properties are high melting point, low vapor pressure, ductility at room temperature, and high strength. Rhenium powder is quoted at about $2000 per lb.; no doubt the price reflects a lack of demand and will be reduced as production rises to greater levels.

Among the unusual physical properties of rhenium are its density – the fourth highest among the elements; its melting point, which is second only to graphite and tungsten; and its vapor pressure, which is much lower than that of either tantalum or tungsten. Although it oxidizes catastrophically on heating in air, it is stable in hydrogen or vacuum.

Rhenium, unlike tungsten, is not attacked by the "water cycle" which produces failure of tungsten filaments in vacuum tubes by continuously depositing tungsten on the cool tube walls.

Rhenium has been shown to be resistant to molten tin, zinc, copper, and silver, although it fails in aluminum, nickel and iron. It is also unattacked by aluminum oxide during 7000 hr. at 2900° F.

Many of the mechanical properties of rhenium are interesting: Its modulus of elasticity is exceeded only by osmium and iridium, its tensile strength at room temperature is higher than tungsten, and it is appreciably ductile at room temperature in contrast to tungsten. At elevated temperatures, the ductility of rhenium is poor, although in tensile and



Uncommon Metals . . .

creep-rupture properties it is superior to tantalum, columbium, and tungsten up to at least 2500° F.

The main potential applications of rhenium include electron tubes, and contacts in electrical relays and switches. Its use in electron tubes is attractive because of its inertness to the "water cycle", its strength, and its refractory nature. The applicability of the metal and several binary alloys with tungsten and molybdenum is currently being investigated.

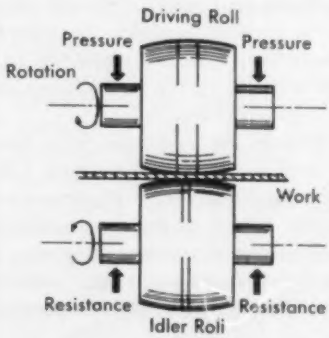
Rhenium as a contact metal has already been put to limited use in magnetos for marine engines. In this case, its resistance to corrosion in salt water combined with its resistance to electrical erosion and its high strength and ductility make it especially attractive. Its use is indicated for other applications requiring these properties, such as pen points.

For measurement of very high temperatures, thermocouples of rhenium with tungsten, molybdenum, or tantalum are usable to about 4500° F. A.G.C.

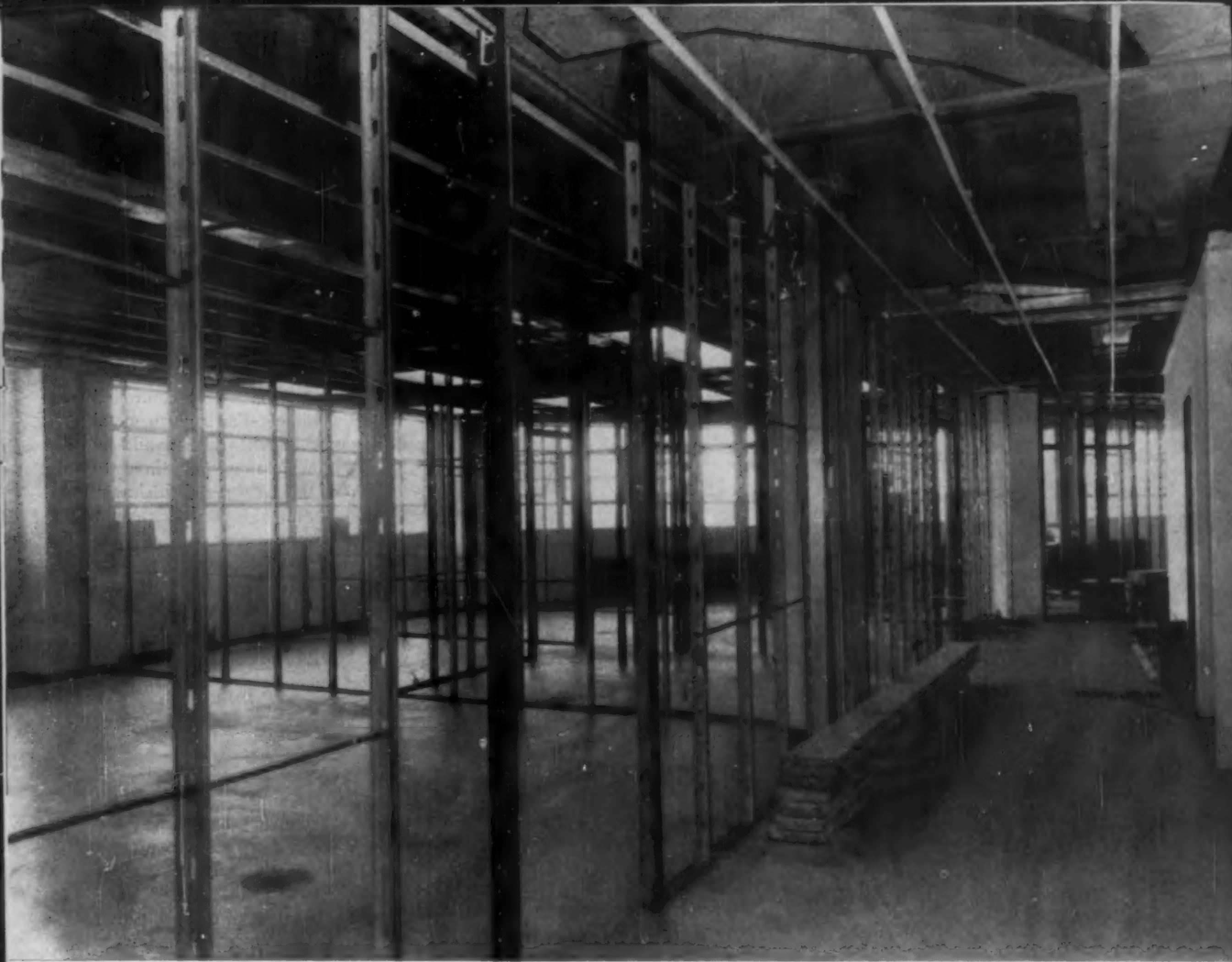
Weld Failures Overcome By Roll Planishing

Digest of "Roll Planishing Improves Weld-Joint Efficiency and Quality", by H. L. Meredith and B. R. Russell, *Welding Journal*, Vol. 36, February 1957, p. 113-117.

INCREASED YIELD and tensile strengths, slightly decreased elongation and improved fatigue strength are among the principal effects of roll planishing inert-gas arc welds in stainless steel and aluminum alloy sheet materials. An aircraft company was experiencing weld joint failures in aluminum alloy nose cone sections of the Corporal missile, and in the effort to correct the trouble turned first to cold working by hammer planishing the longitudinal welds. Although failures were eliminated, hammer planishing was too slow and required skilled metalsmiths so a 10-ton heavy-duty roll planishing machine was built. It was proof tested by planishing square butt welds, made by the submerged-arc process in 12-gage mild steel. The two rollers of the ma-



chine are diametrically opposed and are shaped to exert pressure at a small contact area. The top roller is the driver, the lower the follower (see diagram). Magnitude of the output load can be adjusted pneumatically, from 0 to 20,000 lb. Hence, if a weld ¼ in. wide is to be roll planished, a compressive force



"STRONG. FIRE-RESISTANT. CORROSION-RESISTANT. THAT'S WHY WE USE WEIRZIN® IN OUR STUD SYSTEMS!"

says G. A. Stevenson, vice president of Penn Metal Company, Inc., Parkersburg, W. Va., maker of PERMALOCK nailable metal stud systems.

"Broadly speaking, our choice of Weirzin electrolytically zinc-coated steel is based on two factors: performance in our products and performance in our production lines.

"With Weirzin, of course, our stud systems have the strength, rigidity and high degree of fire resistance inherent in steel. And because Weirzin's zinc coating is completely integrated with the steel, we have the added assurance of a corrosion-free life for our systems.

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"Briefly, we feel that Weirzin has helped us to produce a quality product that gives our customers solid value at low cost."

Strong! Highly resistant to fire! Highly resistant to corrosion! Easy to fabricate! That's Weirzin electrolytically zinc-coated steel. For more information on Weirzin send for free booklet. Write Weirton Steel Company, Dept. S, Weirton, West Virginia.

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Roll Planishing . . .

as high as 416,000 psi. will be attained if the driver roll makes ⅛-in. wide contact at 130,000 lb.

Correct application of the planishing process depends upon six variables: base metal thickness, weld width and contour, weld reinforcement height, roll planishing pressure, surface speed, and surface finish. Of these, weld reinforcement height and width are the most important and must be rigidly controlled during welding. For a given metal thickness, the weld width should be held within a range of three to five times the base metal thickness. Where filler metal is used, the height of weld reinforcement for both the weld bead crest and root should be held approximately flush. Where no filler wire is used and the weld joint is merely fused together, the weld bead height above the base metal surface is generally zero or concave; therefore it is necessary to control the concavity in metal thicknesses of 0.020 to 0.070 in., that is, concavity should never be greater than 0.010 in. deep. If the welding bead is a convex shape, then the reinforcement should not be greater than 20% of the metal thickness above the surface.

Other objectives of roll planishing are to relieve weld shrinkage strain and flatten and smooth weld surfaces. Consequently it is necessary to control cross-sectional area of the weld. Just enough weld reinforcement is required so that it may be compressed enough to refine the surface grain structure, counteract shrinkage strain and be flattened as well.

Loss in weld joint strength is attributable to *(a)* loss in tensile strength due to the weld being a cast metal, *(b)* loss in ductility, *(c)* notch effect caused by abrupt change in thickness at the weld edge, and *(d)* enlarged grain structure at the heat affected zone.

Roll planishing is limited only by the characteristics of the weld joint configuration and the metallurgical limitations of the base metal. Thus, a square butt weld in 0.040-in. thick 1100-0 aluminum may be planished several times at 40 psi. pressure, but a square butt weld in 0.040-in. thick Ti-75 titanium may be planished only once.

A. H. ALLEN

Radiographer Harold B. Allen of TWA, shown on the wing of a TWA Constellation, is placing the x-ray machine in position to check the lower wing skin of the inboard engine nacelle.

"For critical aircraft inspection,

TWA uses Du Pont x-ray film"

reports Mr. Norman W. Grotz, Manager of Inspection at Trans World Airlines Overhaul Base in Parkville, Missouri

Each TWA airliner is fully inspected after each 3000 hours of flight time to conform to TWA safety requirements. The use of x-ray has enabled TWA to save approximately 150 man-hours per major overhaul and has made it possible to accurately check structural integrity of areas invisible with other methods.

Most of the film used at the Parkville Overhaul Base is Du Pont x-ray film. Explaining why, Mr. Grotz says, "We tested all available x-ray films to determine their suitability. Du Pont film met all of our stringent requirements, including fine grain for visualization of critical detail. And the service of the Du Pont Technical Representatives is excellent—an important factor in our use of this film.

"Some of the vital checks we make with Du Pont film are for foreign particles in the engine oil coolers, various hydraulic cylinders and the engine nacelles," continues Mr. Grotz. "The bottom skin of the wing, ⅛ inch aluminum, is subjected to heavy stress. With Du Pont film, we can easily check the bottom skin through four other layers of metal and feel confident about the accuracy of our findings."

Mr. Grotz is in charge of inspecting each of TWA's 135 Constellations. "By combining technical know-how," he concludes, "with fine equipment and materials like Du Pont x-ray film, we are daily improving our inspection procedures while maintaining TWA's fine safety record in the sky."

For quality you can depend on, with the finest technical service, use Du Pont Industrial X-ray Film. If you want more information, call the nearest Du Pont Sales Office, or write Du Pont Photo Products Department, 2420-2 Nemours Building, Wilmington 98, Delaware. In Canada: Du Pont Company of Canada (1956) Limited, Toronto.

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Formation Mechanism of Graphite Nuclei

Digest of "Mechanism of the Influence of Preliminary Quenching of White Cast Iron on the Formation of Graphite Nuclei", by A. F. Landa and V. D. Yakhnina, *Metallovedenie i Obrabotka Metallov* (Russia), No. 12, 1956, p. 46-50.

THE PROGRESS of graphitization during annealing (malleablizing) of white cast iron depends on the number of graphite nuclei that are present. The greater this number the faster is the graphitization process. Among the methods for increasing the number of graphite nuclei are: increasing the amount of silicon, modifying the iron, raising the annealing temperature, and preliminary quenching of the white iron. Although this last method has not been widely applied because of technical difficulties, it is interesting because of the light it can shed on the mechanism of formation of graphite nuclei.

Various opinions are held concerning nucleus formation in the graphitization process. Some authors believe that the nuclei form from the solid solution and appear at the boundaries between austenite grains. Others believe that cementite is the source of the nuclei and that they form preferentially at cementite-austenite interfaces. The rate of graphitization would be increased, according to either of these theories, by the formation of microcracks during a quenching treatment that produced martensite.

To obtain further information on this problem, a study was made of white iron castings containing 3.3% carbon and 0.54% silicon. Prior to a graphitization treatment at 1560° F., the specimens were given a 5 hr. degassing treatment at 570° F. plus one of the preliminary treatments listed in the table. The Brinell hardness of the unannealed castings was 660. The hardness values of the table show that the specimen quenched from 1650° F. and then annealed at 1560° F. graphitized more rapidly than the specimen quenched from 1435° F. This was explained as follows: The secondary cementite in the specimen quenched from 1435° F. was dissolved at 1560° F. while that in the specimen quenched from 1650° F.

was not. The cementite particles in the latter specimen were the source of the more numerous graphite nuclei that could be seen under the microscope.

To distinguish between the effects of microcracks (produced by water quenching) and the effects of cementite particles, some specimens were given a milder quench – into a lead bath at 615° F. The hardness data of the table show that the rate of graphitization was again faster for the specimen quenched from a temperature above the annealing temperature employed. That is, undissolved cementite particles were again serving as sources of graphite nuclei. However, the rate of graphitization of the specimen quenched in the lead bath was lower than that of the specimen quenched from the same temperature but into water. This effect was attributed to the absence of microcracks in the specimen given the milder quench.

The last preliminary heat treatment listed in the table shows that a tempering operation following quenching accelerates graphitization relative to an untempered specimen. This result is reasonable since the small cementite particles produced during tempering can serve as sources of graphite nuclei.

A. G. Guy

Weather Influences Hydrogen in Steel

Digest of "Hydrogen in Electric Steelmaking", by T. W. Merrill, *Vancoram Review*, Vol. 12, No. 2, Fall 1957. p. 14-15.

VANADIUM CORP. of America undertook an experiment in the expectation of establishing quantitatively the effect of some of the variables which determine the final hydrogen content in steel. The experiment work was done in cooperation with Battelle Memorial Institute and Green River Steel Corp.

S.A.E. 4340 steel, made to aircraft quality specifications, was produced in a 70-ton basic-lined electric arc furnace. The variables that it was hoped to evaluate and which were to be intentionally varied were as follows: (*a*) The melt-down carbon and the rate of carbon oxidation; (*b*) the method of carbon oxidation,

Weather Influence . . .

whether oxygen gas, mill scale or iron ore; (*c*) moisture content of the lime; (*d*) moisture content of the mill scale and ore used; (*e*) the time at which alloy additions were made; and (*f*) the method of deoxidation.

Unfortunately, these experiments had to be discontinued after four heats had been studied. However, the first two heats were made on warm, rainy days while the second two were made on cool, dry days. This introduced an unintentional variable that proved to be of major importance.

Experimental Technique — Samples for the hydrogen determination were taken at frequent intervals throughout each of the heats, using a modified Taylor sampling device. A spoonful of steel was taken from the furnace or pouring stream, killed with aluminum, and the sample drawn up in a tapered copper cylinder by suction. The resulting test cylinder was removed from the copper tube as quickly as possible and placed in liquid nitrogen, where it was kept for several days until it could be analyzed for hydrogen by the vacuum fusion method.

Results — It was found that the hydrogen content of each heat decreased from its initial value during the oxidation period to a minimum value corresponding to the end of the oxidation period, after which it increased steadily until the heat was tapped. While the initial value of hydrogen after the charge was melted varied from about 2½ to 5 ppm., the minimum content at the end of the oxidation period was about the same for all the four heats — between 1½ and 2 ppm. The rate of subsequent increase in hydrogen content was similar for the first two heats, and this rate was greater than that for the second two heats. The maximum hydrogen content was greater for the first two heats than that for the second two heats.

It appears that the weather, or more specifically the moisture content of the air in the furnace, *was the most important factor* in determining the rate of hydrogen absorption into the molten steel. Variations in the rate of carbon oxidation did not appear to have influenced significantly the total quantity of hy-

(Continued on p. 158)

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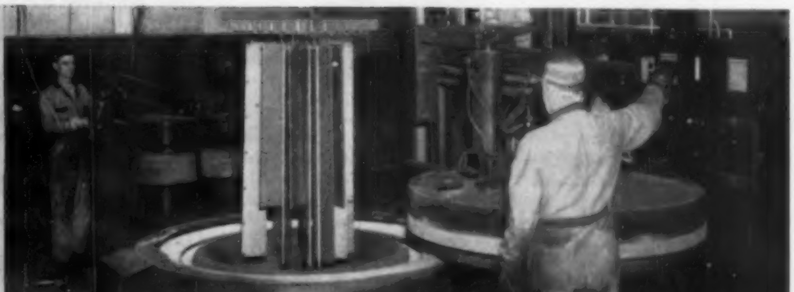
"This equipment took a sizable bite out of our limited expansion capital," says Carl H. Muehlemeyer, President of O. T. Muehlemeyer Heat Treating Company, commercial heat treaters in Rockford, Ill., "but we chose it deliberately after much consideration because we know that with it, we can give our customers the quality and service they require at a competitive cost."

Muehlemeyer points out that, "This furnace is part of a quality-control expansion program extending over the next several years. It reached us from Leeds & Northrup ready for installation with complete instrumentation for Speedomax temperature control and Microcarb atmosphere control."

Only recently has a complete line of gas-fired Homocarb furnaces, equivalent in design, construction and instrumentation to electrically-fired units been introduced. Combining precision control of carbon potential with the economy of gas-firing, these furnaces can be used interchangeably for case carburizing, carbon restoration, homogeneous carburizing or hardening. These factors strongly influenced Muehlemeyer's choice.

A load of SAE 4140 steel slidebars being unloaded from Muehlemeyer's gas-fired furnace. Carbon and temperature control panels can be seen at right. Above is the same furnace . . . measuring 15 feet high by 6½ feet in diameter . . . ready to leave the L&N shipping dock in Philadelphia.



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by Carl F. Joseph
Technical Director

CENTRAL FOUNDRY DIVISION
GENERAL MOTORS
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.....The metallurgy of strength and

The secret of a stronger iron casting lies in the composition, the melting and the heat-treating processes. Perhaps I should use some other word than "secret," because the fact is well known today, but in 1925, when we started our search for a stronger iron, the principle was well known only in respect to steel.

Our research led us to think that heat-treating could improve iron as well. After considerable experimentation, we learned how to arrest the malleablizing process to produce an improved pearlitic malleable iron . . . an iron that compares favorably with the properties of a good grade forged steel. It is from the words "Arrested Malleable iron with Steel-like characteristics" that the name "ArmaSteel" was coined.

The raw materials and melting process for ArmaSteel are very similar to those of our malleable iron . . . the major difference being in the heat-treat cycle. In the cupola, we melt steel scrap, ferrosilicon, and remelt. We add .0025% boron to the charge to assist in breaking down carbides during malleablizing.

Next, the molten iron is tapped into a forehearth where it is desulphurized with soda ash. This removes small particles of slag and impurities, thus improving machinability of the casting. After refining in an electric furnace, the iron is tapped into ladles.

To improve the physical properties on certain castings, .007% bismuth is added as a ladle inoculant: this stabilizes the carbides during the initial freezing of the metal. On heavy castings such as the Pontiac crankshaft, up to .02% bismuth is added. This bismuth-boron combination is a new development.

I mentioned before that the heat-treating of ArmaSteel greatly affected its properties. Actually, we use several different heat-treatments to produce the several ranges of ArmaSteel. All are alike during the malleablizing cycle, where the massive carbides are eliminated. Malleablizing requires about 20 hours: the castings are held at 1750°F. for 10 hours, and near the end of the cycle are dropped to 1650°F., after which they are air-quenched. Brinell hardness at this point is around 300.

Tempering brings the Brinell hardness down to customer's specifications. We produce two standard Brinell ranges of air-quenched and tempered ArmaSteel . . . BHN 197 to 241 (3.9-4.3 mm.), and 163 to 207 (4.2-4.7 mm.). The castings are tempered in a recirculating furnace. The harder material is in the furnace for a total of six hours and forty minutes, and is held at heat for three and one half to four hours at 1270° to 1290°F. The softer material uses the same time cycle but higher heat . . . from 1320° to 1340°F.

For automobile crankshafts, a special hardness range is used. The ArmaSteel is air-quenched and tempered, but the tempering is for six hours at 1200°F., which produces a harder material (BHN 217 to 269).

Two other types of ArmaSteel are produced by reheating the air-quenched castings to 1600°, holding at heat for thirty minutes, then oil-quenching. These are then tempered for three and one half hours at 1170° to 1190°F. BHN is 241 to 269 (3.7-3.9 mm.) and 269 to 302 (3.5-3.7 mm.).

I've gone into detail on heat-treating because it has such a great effect on mechanical properties. Tempering directly controls the amount of combined carbon in the matrix, and this in turn dictates how hard and strong the ArmaSteel will be . . . the higher the combined carbon, the stronger, harder, and less ductile the casting. Thus, the engineer can choose the combination of properties best suited to his application. I can best explain the results of this careful heat-treatment by giving you a brief list of the mechanical properties of ArmaSteel.

1. *Machinability* . . . Because of the carbon nodules in the pearlite matrix, the machinability of ArmaSteel is generally from 10 to 30 percent better than that of steel forgings of the same Brinell. Improvements of up to ten times longer tool life and three times more pieces per machine have been shown.

73-A

2. *Selective Hardening* . . . ArmaSteel responds readily to localized hardening, either by flame or induction methods. A minimum of Rockwell "C" 50 is obtainable on such parts as shifter yokes, rocker arms, and gears. Some applications use the lead immersion or hot salt bath methods, followed by an oil-quench.

3. *Bearing Properties* . . . ArmaSteel is such an efficient bearing material on a hardened steel shaft that bronze bushings are often eliminated. The automotive rocker arm illustrates this excellent non-seizing property in metal-to-metal wear.

4. *High Yield Ratio* . . . The oil-quenched and tempered ArmaSteel has a minimum yield strength of 80,000 psi and ultimate strength of 100,000 psi, making it ideal for highly stressed parts.

5. *Fine Machine Finish* . . . A mirror-like finish can be produced on ArmaSteel. Diesel pistons are an application where this fine finish reduces friction wear to a minimum.

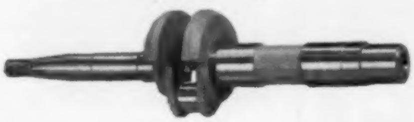
6. *Damping Characteristics* . . . In both small engines and in automotive engines, ArmaSteel crankshafts exhibit a fine damping capacity that aids quiet operation.

7. *Wear Resistance* . . . ArmaSteel withstands excessive wear under heavy loads at high speed.

8. *Fatigue Life* . . . ArmaSteel has good resistance to fatigue, giving maximum endurance and long life.

As countless and varied applications have proven, ArmaSteel is an outstanding engineering material. For information on how your product can benefit from this modern casting metal, write for our "ArmaSteel" catalog.

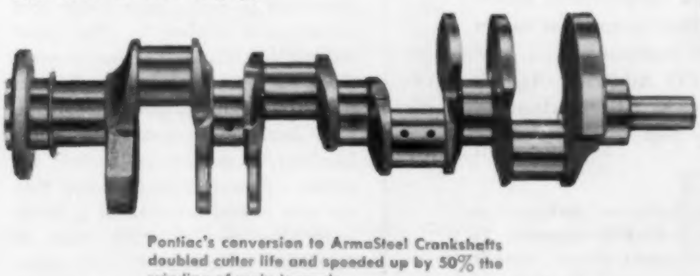
ARMASTEEL® from the standpoint of machinability



ArmaSteel small horsepower engine crankshafts provide good damping qualities and modest cost due to excellent machinability.

ArmaSteel's adaptability to localized hardening pays off especially well on these automotive rocker arms.

Universal joint yokes of ArmaSteel stand up under severe stresses to same extent as former SAE 1145 or 1151 forgings.



Pontiac's conversion to ArmaSteel Crankshafts doubled cutter life and speeded up by 50% the grinding of main journals.

Because of its excellent wear resistance, oil-quenched and tempered ArmaSteel with a Brinell of 241 to 269 has replaced an SAE steel forging for this automotive reverse internal gear.

CENTRAL FOUNDRY DIVISION

GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN • DEPT. 19

Weather Influence . . .

drogen removed from the steel. The rate of hydrogen absorption and the total time that the steel was in the furnace following the oxidation period appear to have determined the final hydrogen content of the steel at tap. The effect of the other variables introduced during the experiment appear to have been masked by the stronger influence of the moisture content of the air.

A.G.G.

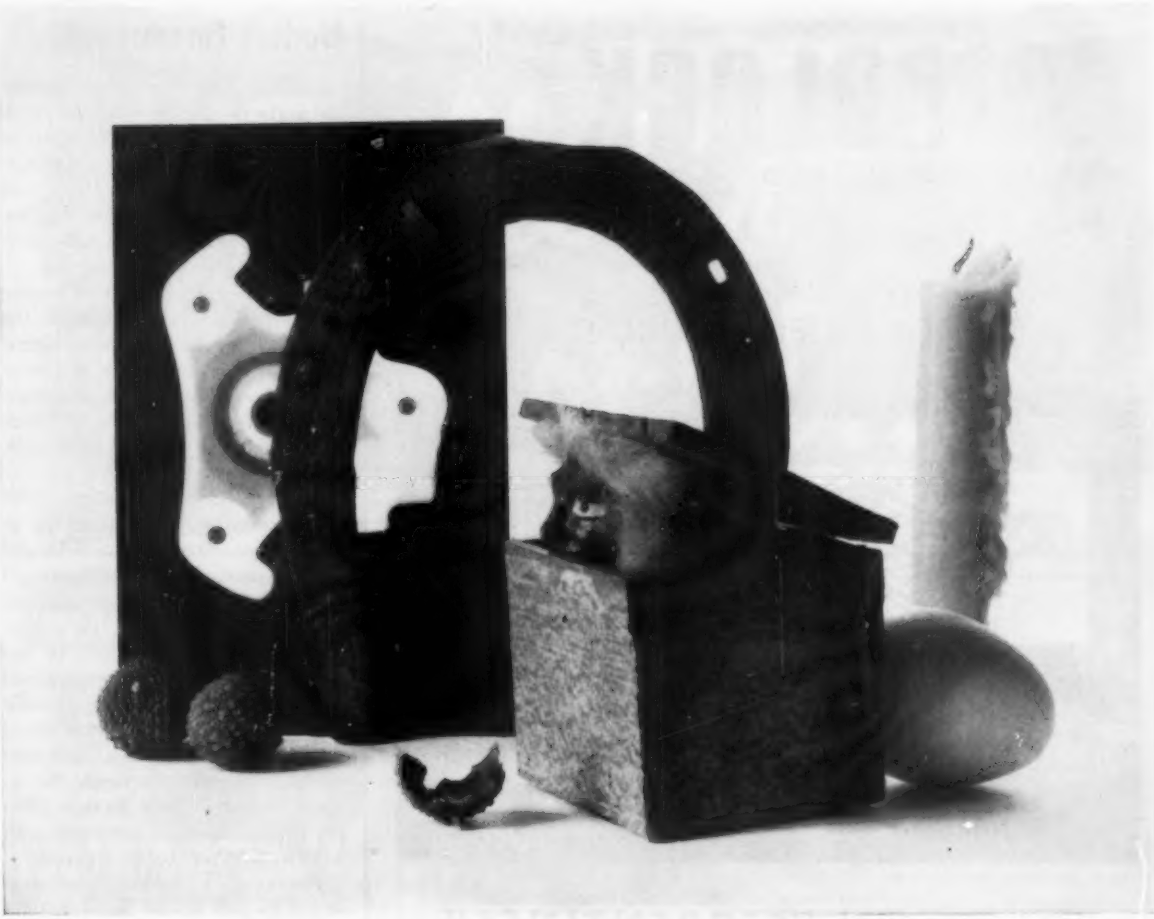
Forecast of Nuclear Power Development

Digest of "The Latest Prospects for Economic Nuclear Power", by W. Kenneth Davis and Louis H. Roddis, Jr. Paper presented at 5th Atomic Energy in Industry Conference, National Industrial Conference Board, New York, 1957, 17 p.

The authors have turned to prophecy of tomorrow's nuclear power climate, and like most weather prognosticators, allow for possible portents of change before the newspaper announces them the next morning.

In considering whether or not a proposed new plant should be nuclear-fueled, a company is interested in the cost of the plant over its useful life, not just at the start. Thus, the decision might be to build a nuclear plant, even though it is not likely to be competitive at first, because nuclear fuel costs will decrease over the next 30 years or more, while conventional fuel costs seem likely to slowly increase.

A given utility company may be interested in authorizing design and construction of plant X. This plant will not actually start operation until three or four years later. Cost at time of beginning operation will be high because of special problems involved in start-up of nuclear reactors. It would be expected that the cost would stabilize at a lower level after two or three years of operation. Presumably this stabilized cost would be predicted with a fair degree of assurance before the project was authorized. Following achievement of stabilized costs, there is likely to ensue a long-term slow decline in costs for plant X as a result of lower nuclear fuel costs.



How to candle a horseshoe!

If castings were like eggs a simple candle would solve all inspection problems.

Getting inside things to "have a look around" is unfortunately a somewhat more critical process.

And since life itself often depends upon the delicate layer of silver that reveals flaws, only an X-ray film having superb gradation and tonal separation can be depended on in routine as well as specialized work.

And tonal separations are the very characteristic that makes Ansco X-ray films special. That's because only Ansco X-ray films are critically coated to tolerances that provide unequalled quality and uniformity. Ansco X-ray films . . . for candling horseshoes!

Ansco

X-ray

Ansco, a division of General Aniline & Film Corp., Binghamton, N. Y.

Nuclear Forecast . . .

This factor also might prove influential in the decision to build the plant.

These factors have been cited to counter the argument sometimes advanced that nuclear plants will not be built simply because they are not competitive with fossil-fueled plants at the time of conception.

Plants which will go into service in the United States through the year 1959 belong to an experimental period during which there can be no hope of achieving costs competitive with conventional fuels. These costs may range from 20 to 50 mills per kw-hr.

Plants built from 1960 to 1964 will be what may be considered as the first generation of true industrial nuclear power plants. These will build on the technology and experience accumulated in the design, construction and operation of the earlier plants and may be expected to achieve costs from 10 to 13 mills to per kw-hr., compared to 4½ to 9 mills for present day coal-fired plants. Capital costs would be expected to range from $300 to $400 per kw. of capacity, compared with $115 to $180 for coal-fired plants.

Plants of a second generation would go into service between 1965 and 1967. These should provide power for a cost of 9 to 11 mills, because of increase of plant size, more knowledge of safety needs, and less costly materials.

Following these, estimated further cost reductions will take place, reaching 6 to 7 mills by 1980. This would make nuclear power competitive with conventional plants in all parts of the United States except a few locations with very low fuel costs.

Based upon the preceding postulates and extrapolated estimates of cost, the amount of nuclear power is expected, as of the time of writing, to increase fairly rapidly after the end of 1959, at which stage there should be ten plants having an output of 130,000 kw.

After the time interval required between planning and completion of second-generation plants, say by 1967, a phase of very rapid expansion is expected to ensue until 1980, when about two-thirds of all capacity will be nuclear powered.

KARL F. SMITH

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers

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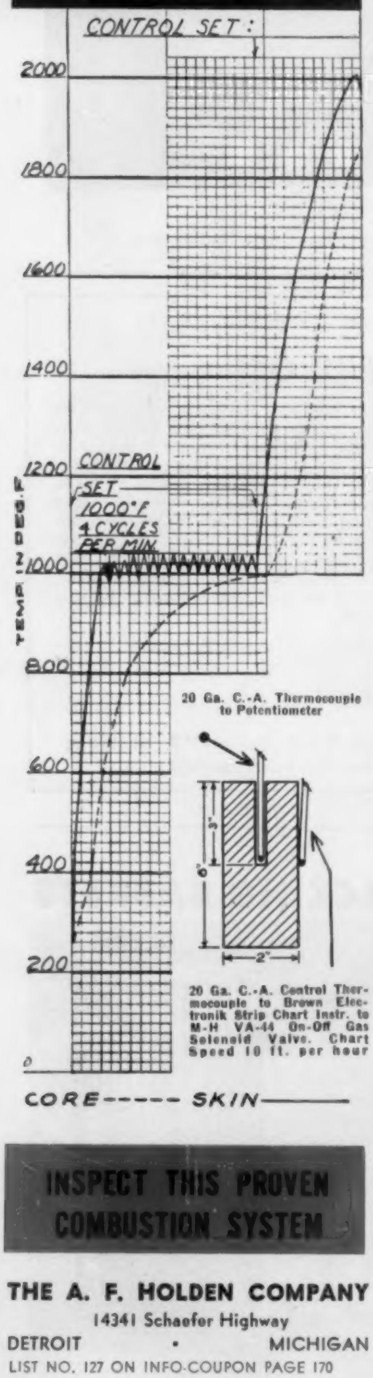
Firing Rate: 50,000 B.T.U. Per Sq. Ft.
Blower Air — 117 C.F.M.



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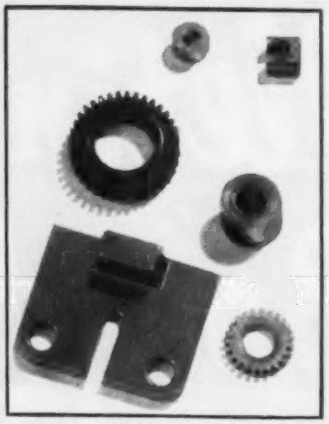
carburized tensile strength to 200,000 psi.



Supermet combines the economy of powder metallurgy with the properties of controlled carburization to give you solid steel parts at low cost. Seven ranges of properties available in electrolytic iron; we also invite stainless steel parts. As an indication of accuracy, we are currently pressing AGMA commercial class 4 spur gears. Send a part print for evaluation.

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free technical literature

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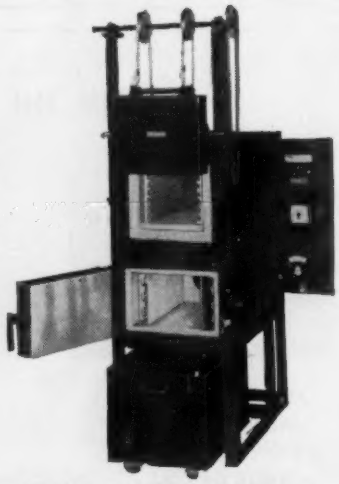

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Drawing furnace has a maximum of 800° F.* Quench tank included with the exception of the largest standard model.

Model	Chamber Size H.	W.	L.	Prices 2000° F.	2300° F.
8055 A	6" x	6" x	12"	$ 865.00	$ 975.00
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*Also available up to 1250° F.

WRITE FOR FREE LITERATURE, SPECIFICATIONS and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

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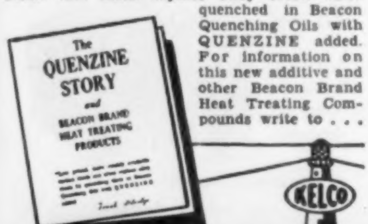

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IMMERSION HEATER
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Available from your Electroplating Distributor

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WIRETEX custom built MUFFLES

assure labor saving operating efficiency!

Features: • High crown • Extra braces • Capacity for holding shape • Double secured weldments • Strict adherence to specifications • Quick delivery • Low cost

ALL SIZES ALLOYS CAPACITIES

WIRETEX designed MUFFLES offer exceptional opportunities to lower costs. Built to take extremely high temperatures and strong atmospheric conditions. If you have a sintering furnace problem or are dissatisfied with the results you are now getting, let us help you.

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Wiretex mfg. co.

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Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems, economically, efficiently, safely! Write today!

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DIV. OF RANDALL MFG. CO., INC.
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RUST-LICK IN AQUEOUS SYSTEMS

Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

Send for Brochure: The ABC of Rust-Lick for Rust Prevention

PRODUCTION SPECIALTIES, INC.
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BOSTON 16, MASS.

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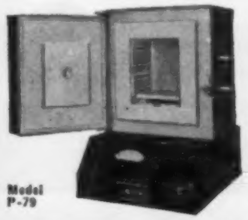
PRODUCED AND PRICED RIGHT FOR YOUR ELECTRIC FURNACE NEEDS

DYNA-TROL

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models



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$1325.00
Other Sizes and Arrangements Available

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SIR PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

20x22	G.E.	48KW	1200°F
28x28	Lindberg	52KW	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	1850°F

CONVEYOR TYPE RECIRCULATING

72x40'x30	Surface	RlrHrth Gas	1250°F
27x15'x12	R&S	MshBlt Gas	1250°F
36x33'x12	Despatch	MshBlt Gas	875°F

BOX TYPE RECIRCULATING

7'x7'x5'	Richards	84KW	450°F
6'x12'x42"	Lindberg	Gas	1250°F
4'x15'x6'	Despatch	Gas	850°F
24"x36"x24"	Lindberg	45KW	1400°F
66"x16'x76"	Lindberg	180KW	1250°F

PIT TYPE CARBURIZERS

14x18	L&N Vapo	11KW	1850°F
14x18	L&N Homo	30KW	1850°F
20x36	L&N Homo	72KW	1850°F
10x20	HeviDuty	14KW	1500°F
25x48 (New)	L&N Micro	100KW	1850°F

BRAZING TYPE

18x42x12	Lindberg Pshr	60KW	2500°F
28x17'x12	G.E. RlrHrth	320KW	2050°F
62x18'x24	G.E. RlrHrth	655KW	1650°F

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19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

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Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load . . . maximum error plus or minus $2\frac{1}{2}$ kg

Write for Bulletin No. A-18

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

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WRITE, WIRE or PHONE FOR YOUR CATALOG
Today

Star Stainless screws have clean—bright—shiny—heads

STAR STAINLESS SCREW CO.
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Telephone: CLifford 6-2300
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CORROSION RESISTANT

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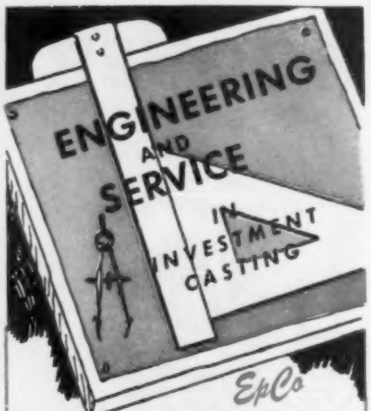

A PROVEN DEPENDABLE SOURCE

FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

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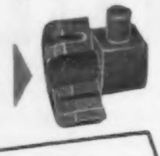
Special Feature —Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.



ENGINEERED PRECISION CASTING CO.
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PRODUCTS FOR SPECIAL METALLURGICAL APPLICATIONS

Complete range of stock sizes in rods, blocks and tubing available. Also, your custom requirements of specially machined articles can be promptly produced.

PREFORMED SHAPES FOR VACUUM FUSION ANALYSIS

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SPECTROGRAPHIC ELECTRODES

Recognized as the standard of the world, United's rods, powders and wide range of preformed electrodes are available in the right sizes and designs for your spectrographic work.

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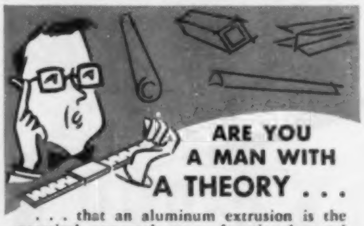

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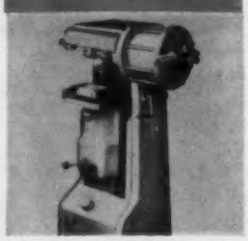
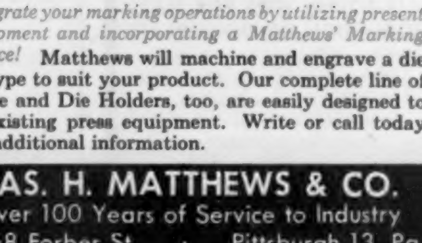
MARKING DIES



Matthews also feature a complete line of General and Special Purpose Machines. Send for Bulletin GPF-200.



Integrate your marking operations by utilizing present equipment and incorporating a Matthews' Marking Device! **Matthews will machine and engrave a die or type to suit your product. Our complete line of Type and Die Holders, too, are easily designed to fit existing press equipment. Write or call today for additional information.**

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Over 100 Years of Service to Industry
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Producers and Sellers of

TITANIUM POWDER

−40 to +300 mesh

High Purity	99.2% Pi
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Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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90-35M Van Wyck Exp., Jamaica 35, N.Y.

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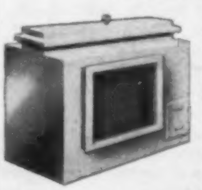
PLATING • PICKLING • METAL CLEANING *FUME SCRUBBING*



• Reasonable initial cost . . . economical in operation . . . no moving parts . . . efficient in performance . . . compact—requires little space . . . standard units—7200 to 57600 C.F.M. Write Dept. "MP" for complete information.

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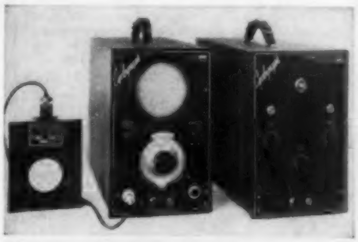
does it better!



THE CYCLOGRAPH, (Model C)

. . . for unscrambling metal mixups

This instrument permits truly high speed, non-destructive sorting of raw, semi-finished or finished parts by their metallurgical characteristics. With the new Automatic Sorter Unit, speeds up to 300 pieces per minute are possible with the use of suitable feeding equipment. Used by leading industrial firms everywhere.

J. W. DICE CO.

"Non-destructive Testing and Measuring Instruments"

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A CABLE SPLICED IN 10 SECONDS!

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Complete Arc Welding Accessories
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Write for Caddy Catalog

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Ask the Man Who KNOWS Stainless Welding . . .

Call Mr. Electrode . . . His years of experience and leadership in providing the correct—

Stainless and Heat Resistant Arc Welding Electrodes
—place a trusted guarantee back of your welding operations.

Automatic Welding . . .
• All Analyses • Coated, Straightened • Cut • Coiled and Spooled

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Temperature Measurement

Industrial temperature measurement with thermocouple pyrometers, with total radiation and optical pyrometers, with resistance thermometers and filled systems thermometers. W. E. Belcher, Jr., D. Robertson, W. F. Hickes—64 pages—6x9 — illustrated — paper cover—$1.00. Clip and send to Technical and Engineering Book Information Service, 7301 Euclid Avenue, Cleveland 3, Ohio.

READERS' INFO-COUPON SERVICE, METAL PROGRESS
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ACHESON

dispersions digest

Reporting uses for

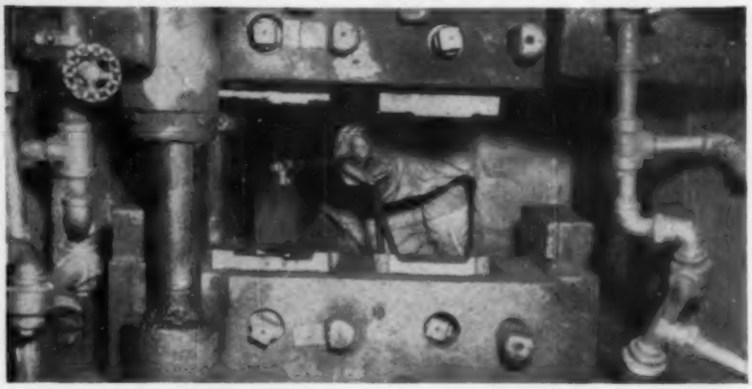
dag® BRAND DISPERSIONS

COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

COLLOIDAL GRAPHITE PROVES IDEAL AS FORGING LUBRICANT

Lubricants to be suitable for use on forging dies for steel and nonferrous metals must be stable under the high temperatures and pressures involved. Besides providing the most effective lubrication for hot-work dies, 'dag' brand dispersions act as coolants. Total advantages gained by using Acheson colloidal graphite, as described in the following applications are: improved quality of the forging, reduced die wear, lower production costs, and improved working conditions.

'dag' dispersion improves quality, cuts costs for Utica Drop Forge and Tool Division. With a large share of their capacity being devoted to the forging of jet engine blades, Utica finds it must maintain high production, consistently high quality, and a competitive price. Blade-forging dies have a comparatively short life due to rapid wear caused by the thinness of the blades, the high pressures required to form the heat-resistant alloys used, and the closer tolerances required. They have found that *every one* of these requirements can be met by using 'dag' colloidal graphite dispersed in water as their



Operator spraying colloidal graphite on both top and bottom die halves before forging jet engine blades at Utica Drop Forge and Tool Division, Kelsey-Hayes Company.

forging lubricant. First, it must withstand temperatures which range from 1950-2200° F. Sprayed on both halves of the die it forms a tightly adhering, smooth, microscopically-thin film that aids metal flow and substantially protects the die itself. In many cases, this has meant fewer finishing operations and therefore higher production, due to the improved quality of the blades. A compressor blade formerly required four blows from upset to finish, with an intermediate heat and tumbling operation. Now, this operation is done in only two blows from original heat. The savings . . . $16,000 a year on this part alone! Add increased life of these precision dies and you can appreciate what a 'dag' colloidal graphite dispersion means to efficient forging. Utica finds water-based dispersions best for press forging, and colloidal graphite in oil the best lubricant for hammers.

Write for additional information contained in Acheson Bulletin No. 426. Address Dept. MP-68.

Concentrated Acheson colloidal graphite being applied to die surfaces before they are put in service.

Pre-treatment and operational use of 'Aquadag' greatly increases die life. Before putting dies into service, a prominent midwestern manufacturer finds that by preheating them to about 250° F. and brushing on a dispersion of colloidal graphite in water, they have generally *doubled* the working life of their dies. When used as an operational lubricant, die wear on a truck body brace die was proved by actual measurements to be only *one-third* the former rate. And this was with 'Aquadag' diluted 1 to 240 in water! . . . Ample proof of the wide coverage, film toughness, lubricity, and basic economy of a "dag" brand dispersion.

Colloidal graphite is resistant to heat, does not react with the die steel, and the extremely small particle size permits an actual adsorption to the metal surface. A water carrier eliminates the usual smoke and fumes thus affording better working conditions and keeping die temperatures down. After the carrier evaporates, a dry graphite film remains which, besides being an efficient lubricant, protects the die from the accumulation of abrasive dust and scale. Die life is extended from 8 to 14 days and production increased by the reduction in downtime.

Specially compounded, ready-to-use forging lubricants containing 'dag' colloidal graphite are available from industrial lubricant suppliers. If you have a forging lubrication problem, it may pay you to call in your Acheson Service Engineer.

ACHESON Colloids Company
PORT HURON, MICHIGAN
A division of Acheson Industries, Inc.
Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Offices in: Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • Milwaukee • New York • Philadelphia • Pittsburgh • Rochester • St. Louis • Toronto

Welding Show . . .

(*Continued from p.* 113)

Brazing – Papers presented at the St. Louis meeting included a study of the bonding of cermets to metals, an evaluation of procedures for testing shear strength of brazed joints, and a general study of brazing metallurgy.

In "Bonding of Cermet Valve Components to Metals", G. M. Slaughter, P. Patriarca, and W. D. Manly (all of Oak Ridge National Laboratory) described the cermets containing varying amounts of titanium carbide, tungsten carbide, and minor additions of complex carbides containing columbium and tantalum, which they successfully joined to Inconel to form high-temperature fluid control valves. Brazing this specialized component is complicated because many cemented carbides are difficult to wet. In addition, these materials can easily create sufficient stresses during cooling to result in fracture since they have wide differences in coefficients of thermal expansion. Wetting was accomplished by using a brazing alloy of nickel-silicon-boron-iron, or nickel-chromium-silicon-boron-iron, or palladium-nickel. The authors lessened the effect of stresses resulting from differential thermal expansion by using nickel as a sandwich cushion between the cermet and the Inconel.

In the paper, "Proposed Procedure for Testing Shear Strength of Brazed Joints", F. M. Miller and R. L. Peaslee (Wall Colmonoy Corp.) not only propose a new testing procedure (which is sure to stir up a lot of comment in the industry), but they also speak up about the need for a standard specimen and procedure for testing brazed joints. They recommend the adoption of a test bar having a short overlap "to minimize the effect of stress concentrations, and to cause failure in the joint, rather than the base metal."

Although the paper by Nicholas Bredzs and Harry Schwartzbart (Armour Research Foundation) is not quite as broad in its coverage as its title, "Metallurgy of Bonding in Brazed Joints – Part I", implies, it is, nevertheless, a timely study. It describes several mechanisms that occur in joining steel using copper and silver-base brazing alloys. The authors discuss the metallurgical interactions between base metal and filler metal, particularly the dissolving of base metal in molten filler metal, and the structure of the solidified filler metal. They found that filler metal will dissolve up to 4.7% iron which may precipitate, in the form of dendrites, at the base-metal, filler-metal interface or within the filler-metal layer. By using mild steel and high-carbon steel (1.0%C), they established that the carbon content of steel base metal checks the precipitation of iron dendrites – the higher the carbon the greater the number of precipitated iron dendrites. They hypothesized that the saturation of the filler metal with base metal and subsequent precipitation out of supersaturation may be a universal phenomenon in brazing.

Atomic Age – Papers dealing with nuclear energy included two somewhat specialized developments. The first, recently declassified by the A.E.C., dealt with automatic submerged-arc welding of uranium; the second dealt with the use of radioisotopes in welding wire for nondestructive testing.

Welding of uranium by various methods has been under investigation for a number of years. In most of the earlier work an inert-gas, shielded-arc method was used. However, in joining heavy metal sections, this method was not satis-

Welding Show . . .

factory because of the formation of a contaminant oxide in the weld metal. In "Submerged-Arc Welding of Uranium", Gail Hanks, J. M. Taub and E. L. Brundige (University of California) discuss the process in detail. By submerging the molten uranium metal beneath a layer of flux, the inert-gas shield was eliminated in the process.

In all submerged-arc welding, choice of flux is important since the flux refines the molten metal, stabilizes the arc, and has to overcome the pyrophoric nature of the metal. By trial and error the commercial fluxes were eliminated from the picture. A composition of 75% fluorspar and 25% cryolite was found to approach the eutectic composition. The flux was prepared by a "fritting" procedure borrowed from the ceramic industry. High-purity materials were mixed, melted, held at temperature to remove volatile impurities, and then poured into water. The resultant frit was dried and screened.

The 3/16-in. uranium wire electrode was coated with electrodeposited silver. The ¾-in. uranium plates had 30° beveled butting edges. A grooved graphite backup bar was flushed with helium, and the beveled surfaces were electropolished prior to welding. Welding was done with 500-amp. d-c. straight polarity and 28 to 30 v. Speed of travel was about 140 in. per min. The setup is shown in Fig. 3. Weld deposits showed tensile strengths nearly 65% greater, and yield strengths 95% greater than those of the as-cast uranium metal.

Paul Barnes (U.S. Naval Ordnance Test Station) and Gordon Locher (Western Radiation Lab.), in their paper "A Study of the Use of Radioisotopes in Welding Wire and Brazing Materials as a Means of Nondestructive Joint Inspection", suggested radioactive welding wire for automatic welding applications as a check on the uniformity and penetration of the deposit. The metals used in the experiment were alloys of aluminum, iron, and silver.

The Welding Show – Automatic machinery is playing an increasingly important part in production-line welding. Many manufacturers no longer think of themselves purely as

Welding Show . . .

makers of positioners and manipulators, since they now turn out completely integrated automatic welding units. In this category a star attraction of the show was a contour welding device developed by the Lewis Welding and Engineering Corp. An automatic seam-following unit senses out and follows the weld seam accurately whether it is straight, curved or angular. The unit and welding head are mounted on a ram-type manipulator. Minute differences in the welding voltage potential are picked up, amplified and used to control the electromechanical directional drive mechanism. Potential differences and drive mechanism are coupled in a manner to cause the arc to continually seek the center line of the weld joint as the welding head progresses along the seam.

Semiautomatic Welding – Automation is also making its mark in manual welding. No longer is it necessary to use a hot, spatter-covered electrode holder and constantly change electrodes; now it is practical to use a gun-type holder (Fig. 2), cool to the touch, carrying its supply of electrode wire in a spool container.

Your reporter decided to change hats – or in this instance helmets – to try out this development in semiautomatic welding equipment and evaluate it as to (*a*) the practicality of the controls, and (*b*) the degree of skill needed to operate the unit. Controls are simple and foolproof. The weld is started by a squeeze of the trigger (energizing the inert gas and current). The arc is ignited by striking the tip of the electrode on the surface of the base metal in the same way that one strikes a match. In using manual electrodes the operator has to compensate for electrode melt-off and maintain constant arc length; however, the semiautomatic gun compensates automatically.

The first downhand weld, using a National Cylinder Gas "Dual Shield" unit, resulted in considerable porosity, simply because the gun, not held at the correct angle or distance, prevented much of the shielding gas (CO_2) from playing over the weld puddle. The second run produced a solid, automatic-appearing weld. Spatter is much lower than with manual electrodes.

Flux-Cored Electrodes – The above unit employs a flux-cored electrode. Granulated flux is contained within the steel electrode casing, so that the amount of flux fed to the molten pool is accurately controlled.

Several other flux-cored electrodes were demonstrated at the show, including the Arcos Corp. electrode for CO_2 semiautomatic and automatic welding of chromium-molybdenum and low-alloy steels. The Stoody Co. also demonstrated a tubular wire electrode for semiautomatic hard facing.

Magnetic Flux Process – The Linde "Unionarc" process (Fig. 1) is another innovation on a granular flux welding theme. It has two advantages over the submerged method, in some applications: First, it is not affected by gravity and will therefore deposit weld beads out-of-position (your reporter made a fairly acceptable vertical-up weld using a Unionarc unit). Second, the arc is constantly visible.

The arc works in this manner: The wire electrode is continuously fed out of the welding gun coated with a granular flux and shielded in a CO_2 gas atmosphere. At the torch nozzle, the magnetic field surrounding the energized welding wire magnetizes and attracts the flux to the wire. As a result, the wire is "coated' as it approaches the arc.

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Welding Show . . .

Similar hand-held welding units designed by Westinghouse Electric Corp. and Air Reduction Sales Co. were operated by the writer. These units were essentially alike, each having a pistol grip, trigger action, and self-contained spool of wire. Each weighed some 4 lb. loaded (1-lb. spool of aluminum wire). They have a comfortable grip and good balance and appear to be ideal for numerous short-length welds. According to the manufacturers, these units will weld metals such as steel, bronze, aluminum, and magnesium.

Embrittlement in Welded Heat Resisting Steels

Digest of "The Problem of Embrittlement in the Welding of Austenitic Heat-Resisting Steels", by Henry F. Tremlett, *British Welding Journal*, Vol. 4, June 1957, p. 283-287.

THE EFFECTS of silicon and carbon on the formation of sigma phase in a 25% Cr, 15% Ni steel were discussed in a recent paper. As a result of that investigation, further work was undertaken to determine the susceptibility to embrittlement of commercial heat resisting steels and weld metals. The four steels selected had the following analyses:

C	Si	Ni	Cr	W
0.23	1.7	11.5	23.7	3.1
0.27	1.6	12.0	25.7	. .
0.19	1.8	15.8	25.9	. .
0.12	1.8	19.4	25.7	. .

Samples of these steels were solution treated for 4 hr. at 1050, 1150 and 1250° C. (1920, 2100 and 2280° F.) and for 5 min. at 1350° C. (2460° F.). They were then heated for 2000 hr. at either 700° C. (1290° F.) or 900° C. (1650° F.) to form the sigma phase. The samples were heated in a flash butt welding machine before heating for 1000 hr. at 900° C. (1650° F.).

The sigma phase occurred in all the steels at 700 and 900° C. (1290 and 1650° F.) although the mode of occurrence varied. At the weld line it occurred at the grain boundaries, but away from the weld line it depended on the presence or absence of ferrite.

Bend tests performed on speci-

Embrittlement . . .

mens aged for 1000 hr. at 875° C. (1610° F.) revealed that the tungsten steel specimen, solution treated at 1100° C. (2010° F.), had the lowest ductility away from the weld. However, the heat-affected zones of all samples solution treated at 1350° C. (2460° F.) had the same ductility.

This investigation also covered the relationship between the base metal composition and the "as-deposited" weld metal constitution of a number of commercial electrodes comparable to the A.I.S.I. Type 300 series. The study disclosed that silicon and manganese had little effect on heat resisting welds of the duplex tungsten-bearing type and on the austenitic high-nickel welds. The effect of embrittling phases on the bend test ductility depended upon the size, amount, and distribution of the sigma phase, and on the amount of carbides present, decreasing as they increased. The maximum amount of sigma plus carbides which could be tolerated while retaining reasonable ductility was 8%.

High-silicon content was undesirable in the weld metal because it increased the amount of nickel required to avoid ferrite formation and increased the amount of sigma formed in a fully ferritic steel. The reasonable silicon range for commercial 25-15, Cr-Ni wire was found to be 0.4 to 0.8%. This is increased slightly with increased carbon.

As a result of this investigation, the following plate compositions are recommended for minimum embrittlement:

C	Mn	Si	Cr	Ni (min.)
0.12	1.8	0.6	25	19.7
0.15	1.8	0.6	25	18.8
0.18	1.8	0.6	25	17.9
0.21	1.8	0.6	25	17.0
0.24	1.8	0.6	25	16.1
0.27	1.8	0.6	25	15.2

The proposed weld composition for the above steels is:

C	Mn	Si
0.14-0.18	5.0-7.0	1.0 max.

Cr	Ni
23-25	15-17

Bernard Trock

Grain Refinement of Ferritic Nodular Irons

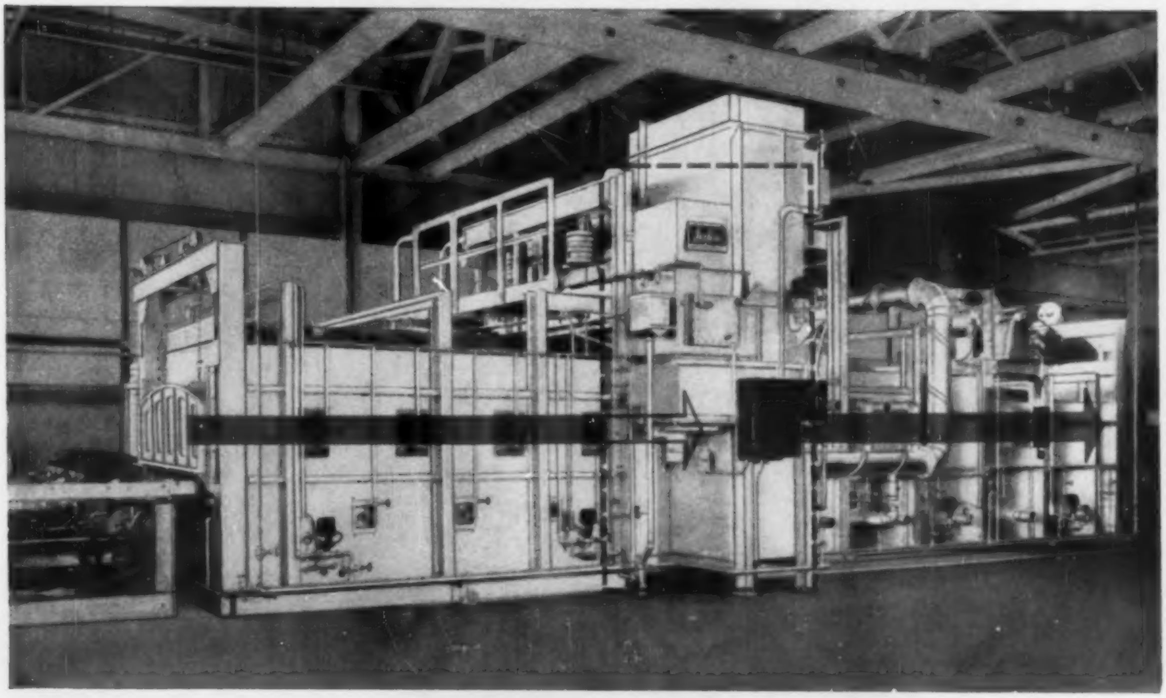
Digest of "The Effect of Grain Size on the Mechanical Properties of Ferritic Nodular Irons", by G. N. J. Gilbert, British Cast Iron Research Assoc., *Journal of Research and Development*, Vol. 6, December 1956, p. 430-435.

The temperature at which the change from ductile to brittle failure occurs in a notched-impact test specimen of ferritic nodular iron is a function of the chemical analysis. To ensure shock resistance, the amounts of silicon, manganese, phosphorus and nickel should be limited. However, yield and tensile strength values increase sharply with increasing silicon and nickel contents. Consequently, the requirements for good shock resistance are not conducive to the development of the best tensile properties.

The problem is aggravated by the

(*Continued on p.* 184)

Superfast cooling for cycle annealing



A furnace-within-a-furnace makes this Surface cycle annealer one of the most versatile heat treat units in the country. It anneals, cycle anneals, and normalizes gear forgings of different size, shape, and alloy at the net rate of 864,000 lbs. per month or better.

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Write for Bulletin SC-146 on cycle annealing.

Surface Combustion Corporation, 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

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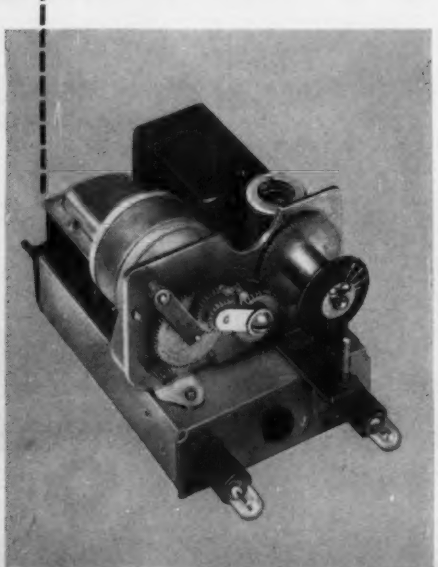

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Nodular Irons . . .

development of processes for adding magnesium to gray iron without using nickel-magnesium alloys; the resulting nodular iron is nickel-free and exhibits relatively low yield and tensile strength values.

In view of these considerations, the influence of variations in heat treatment procedures on tensile properties is of interest.

Previous investigators have shown that annealing below the critical range may have an embrittling influence and have recommended a procedure involving quenching from within the critical range followed by tempering. The present paper concerns the influence of relatively slight variations of the conventional heat treating cycle on tensile properties and ferrite grain size.

Test bars, machined from keel blocks, were put through six different heat treating cycles. Then the microstructures were examined.

Materials treated for 1 hr. and 20 hr., respectively, at 1650° F. had grain structures typical of normally annealed ferritic nodular irons. Finer grain structures were obtained in materials treated at 1560° F. It was concluded that the grain size is dependent on the austenitizing temperature as well as the holding time at this temperature. Material treated at 1470° F. for 20 hr. had a uniformly sized fine-grain structure similar to that occasionally observed in commercially annealed materials with superior impact properties.

Care was taken to hold annealed specimens for a sufficient time, and at a temperature high enough above the critical range to ensure that sub-boundary structures were not obtained in the ferrite grains.

An evaluation of the mechanical properties shows that the ultimate strength increases slightly and the elongation decreases slightly as the ferrite grain size is refined. Impact test values were not sufficient in number to permit the drawing of definite conclusions and all transition temperature curves fell closely together. However, as was expected, the material with the finest grain size exhibited the lowest transition temperature, and the presence of an undesirable sub-boundary structure resulted in a very high transition temperature.

Nodular Irons . . .

The author concludes that improved tensile and impact properties can be obtained if nodular irons are annealed to give a fine ferrite grain size. The improvement in tensile properties is indicated by a substantial increase in yield strength, while the ductile-to-brittle transition temperature is decreased.

Materials are normally annealed to the ferritic condition by holding at a temperature of about 1650° F. for a few hours and then holding at a subcritical temperature of about 1270° F. for an additional length of time. After the 1650° F. treatment, materials may be air cooled and reheated to 1270° F. or simply furnace cooled to 1270° F. If the treatment at the high temperature is carried out at temperatures lower than 1650° F., some grain refinement is obtained. At any given temperature, finer grains are obtained after a short treatment rather than a long one, providing the material has austenitized completely. Very fine grain structures are obtained by holding at a temperature in the austenitic range as close as possible to the upper limit of the critical range.

The austenitizing temperature for annealing nodular irons may sometimes be chosen with the object of decomposing eutectic carbides present in the as-cast condition. The lower the temperature and the shorter the time-cycle, the less readily will this phase decompose. Therefore, if an attempt is made to produce a fine-grained material, care should be taken to avoid the presence of eutectic carbide in the as-cast structure of the iron. HANS HEINE

Periodic Markings on Electropolished Aluminum

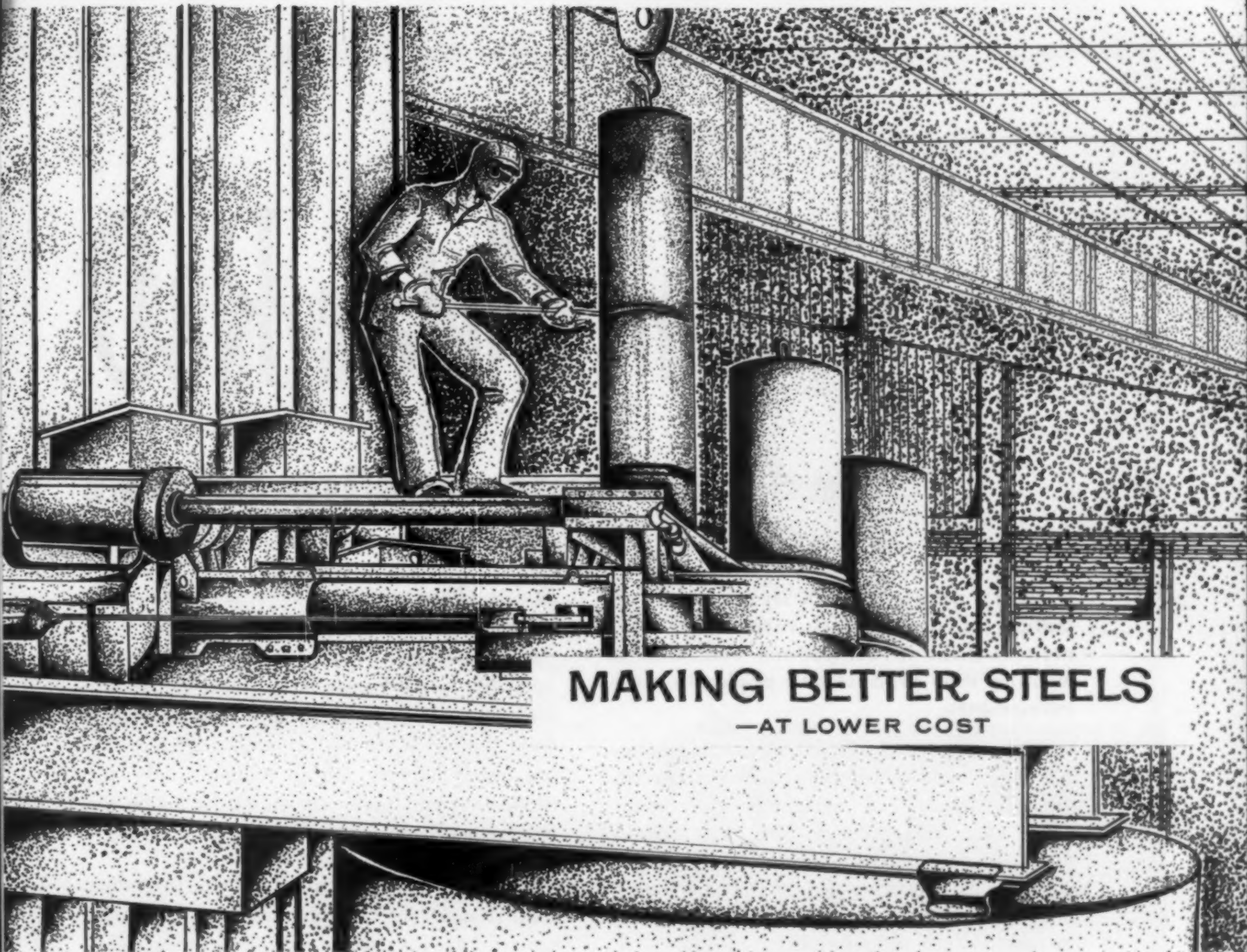
Digest of "Pseudo-Subgrain Structures on Aluminum Surfaces", by N. C. Welsh, *Journal* of the Institute of Metals, Vol. 85, December 1956, p. 129-135.

ELECTRON-MICROSCOPE replicas from anodically polished aluminum often show fine lines equally spaced at intervals of about 0.1 μ. The pattern resembles furrows, and changes direction from grain to grain. The object of this investigation was to examine the possibility that the surface markings are traces of an internal crystal structure.

High-purity rolled and annealed aluminum sheets were anodically electrolyzed under controlled conditions ranging from electropolishing to heavy anodic oxidation. Specimens were prepared at voltage intervals up to the breakdown limit of the anodic layer.

It became evident that the furrow-like structure first reported is only one of many patterns which the polished surface can aquire. Variations were due to (*a*) complete changes of structure associated with changes in the condition of electrolysis, and (*b*) modifications of pattern from grain to grain, related to the crystal orientation of the substrate. In category (*a*) three basic structural patterns, designated as "furrow", "dotted", and "globular"

(*Continued on p.* 190)



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Markings . . .

structures, appeared under different regimes of applied potential and bath temperature. The regimes were broadly defined for the perchloric acid-alcohol bath as follows: 0 to 10 v., no detectable structure; 10 to 20 v., furrow structure; 20 to 30 v., a transition range from furrow to dotted structure; 30 v. up to the breakdown limit, dotted or globular structures, the latter appearing only at temperatures below 0° C.

The potential applied to the electropolishing cell appeared to be the dominant factor controlling not only the geometry of the surface patterns, but also the spacing of the structural units 0.03 to 0.3 μ. The spacing between equivalent points of each pattern increased progressively as the applied potential increased. The bath temperature and current density had no detectable influence on spacing.

Structures appearing at the lowest voltages were extremely fine, approaching the resolution limit set by the replicas (250 Å); hence the absence of recognizable patterns may simply indicate inadequate resolution. Structureless zones also appeared at voltages approaching the breakdown limit.

By using direct current from a battery source, instead of rectified alternating current, the applied potential could be increased from 70 v. to 100 v. before breakdown occurred. The voltage range within which furrow-type structures appeared extends up to 50 v. compared with only 30 v. for rectified current. The potential applied during electropolishing appears to be the dominant factor determining the size and pattern of the surface structures.

The notion that the markings represent some regular incoherence in the grain structure of the metal is refuted by these experiments. The changes of pattern and spacing and their dependence on the electric field are incompatible with the concept of a sub-grain structure. The postulate is made that the markings originate from a micro-etch process acting through, and controlled by, a disperse anodic film. The findings emphasize the need for caution in interpreting fine structures revealed by electropolishing.

A. F. Mohrnheim.

Properties and Fabrication of Beryllium

Digest of "Beryllium and Beryllia—Part I and II", by L. David, *Metal Industry*, Vol. 90, June 21, 1957, p. 519-521; June 28, 1957, p. 546.

BERYLLIUM is an outstanding reflector material for neutrons, the elementary particles that produce the chain reaction in the core of a nuclear reactor. When a neutron strikes a beryllium nucleus, it is more likely to rebound than to be absorbed. If a reactor core is surrounded by a beryllium reflector, escaping neutrons will tend to bounce back into the arena of fission and so contribute to the continuation of the chain reaction. Its low neutron-absorption property is also important in the choice of beryllium as a moderator.

As a moderator the element acts to decrease the speed of the neutrons born in the fission process, After repeated impacts with beryllium atoms, the neutrons slow down sufficiently so that a direct impact on a uranium-238 atom is likely to cause another fission reaction out of which new neutrons are born which, in turn, have to be slowed down to continue the process. The slowing-down power is present in beryllium in a most remarkable degree. It is therefore no surprise that the A.E.C. contracted for 450 tons of beryllium metal in August 1956.

The author, L. David, who is a director of the Beryllium Smelting Co., Ltd., has assembled in a brief and concise manner the most important properties and fabrication processes of beryllium and to some extent those of beryllia (BeO). For a more detailed treatment of many subjects, the reader is referred to the A.S.M. book "The Metal Beryllium", published in 1955.

Beryllium is practically as light as magnesium, has good corrosion resistance to water and air and has a high strength-to-weight ratio, more favorable than titanium. These properties, coupled with an elastic modulus of about 40,000,000 psi., account for the interest of the aviation industry in the metal.

The high melting point of the metal (2340° F.) and particularly that of the oxide (4660° F.) make it an attractive high-temperature material. This desirable property in combination with the element's nuclear characteristics promises some new application in high-temperature nuclear reactors. Unfortunately, the health aspect is not sufficiently discussed, and should not be overlooked by anybody planning to use beryllium or especially beryllia.

Chemically, beryllium is closely related to aluminum and its complete separation from this element is difficult. Like aluminum, beryllium forms a protective oxide skin and owes its stability in air up to red heat to this protective oxide layer. Difficulty in joining the metal stems from the ease of oxidation at elevated temperatures, and from inherently low ductility. A high heat of fusion and high specific heat are also contributory causes of difficulty.

Complicated shapes like finned tubing and fluted spacer rods have been fabricated from beryllium

Beryllium . . .

powder by hot pressing at about 1900° F. using pressures of 75 to 1000 psi. Maximum tensile ductility has been observed in powder warm pressed at 800° F. with a pressure of 200,000 psi. Beryllium can be forged at about 1500 to 2000° F. with characteristics similar to those of magnesium.

Beryllium oxide is pure white, light in weight, very hard and brittle with high compressive strength. Beryllium oxide shapes can be bonded without addition of impurities and can be formed after firing with the very best tungsten carbide tools or water-lubricated diamond wheels (Knoop hardness 1250). Beryllium oxide is of greatest advantage where a high dielectric strength with very high thermal conductivity (thermal shock resistance) is required over a wide temperature range. This is why beryllium oxide is employed in aircraft spark plugs, ultra high-frequency radar insulators, and linings used in high-temperature electric furnaces.

Though the high cost of nuclear grade metal has somehow impeded the progress in atomic energy applications, beryllium has found its use in the A.E.C.'s Material Testing Reactor (MTR), in the reactor for the submarine Sea Wolf (SIR), and in the low-power and high-power water boiler reactors (LOPO and HYPO). Other applications of this element in the nuclear industry are undoubtedly forthcoming.

FREDERICK FORSCHER

Oil-Free Bearings

Digest of "Small Oil-Free Bearings", by H. S. White, *Technical News Bulletin*, National Bureau of Standards, Vol. 41, March 1957, p. 35-37.

CLOCKS and similar mechanisms used on aircraft must function reliably at subzero temperatures, and therefore the bearings used in them must operate as freely at such temperatures as at ordinary room temperature. Since excessive friction is produced in bearings at subzero temperatures by increased viscosity and congealing of oils, oil-free bearings are desirable for this service.

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An active and varied solid state research program on both metallic and ceramic materials is vital to the furtherance of reactor development objectives. Since reactor performance is limited by materials' deficiencies, materials of higher performance capabilities and lower cost are urgently needed.

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If you feel you qualify for a career in nuclear power and you are a U. S. Citizen, send your resumé to Mr. M. J. Downey, Dept. #A-57, Bettis Atomic Power Division, Westinghouse, Box 1468, Pittsburgh 30, Pa.

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Oil-Free Bearings . . .

To determine suitable materials for such bearings, the friction and wear characteristics of 81 materials were investigated mostly between −76 and 77° F. These materials included bronze, sapphire, boron carbide, impregnated carbon, and several kinds of plastics with and without various fillers. Friction and wear tests were made at speeds of 3 to 300 rpm. using a hardened stainless steel shaft ¼ in. in diameter with a load of 4.85 lb. Wear tests were also made in thrust bearings against ⅛-in. diameter oscillating shafts with a total load of 2.734 lbs. Oil-free bearing performance was studied in 18 timepieces of various types by noting the accuracy of keeping time in 24 hr. at —76, 77, and 167° F.

The results reported are summarized as follows: Sapphire was the most satisfactory material for pallet stones in timepieces, but may cause rapid wear of moving parts in certain types of unlubricated bearings. Boron carbide and bearing bronze were unsuitable for unlubricated bearings.

Carbon impregnated with a metal such as silver was likewise not sufficiently fine-grained or uniform for the smallest bearings, but such material without lubrication was generally satisfactory with respect to friction and wear.

Polytetrafluoroethylene was not suitable for general use in these unlubricated bearings, although for special applications it might be adequate. Its friction increases below 0° F. Fused coatings of this material also were unsatisfactory. When mixed with about 29% by volume (63% by weight) of 0.5 to 5 μ molybdenum powder, however, this material formed excellent bearings for the conditions under investigation. The coefficient of friction was low and the wear resistance exceptionally good.

Polytrifluorochloroethylene also appeared unsatisfactory by itself in these tests, but when mixed with a filler of 10 to 60% polytetrafluoroethylene and fused at 500° F., a very promising oil-free bearing material was obtained, with greatly improved resistance to wear though its friction increases below 0° F.

George F. Comstock.

The 13th METALLOGRAPHIC EXHIBIT

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Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

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The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

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Metallographic Exhibit
American Society for Metals
7301 Euclid Ave.
Cleveland 3, Ohio, U.S.A.

CLASSIFICATION OF MICROS

Class 1. Cast irons and steels.

Class 2. Carbon and alloy steels (wrought).

Class 3. Stainless steels and heat resisting alloys.

Class 4. Aluminum, magnesium, beryllium, titanium and their alloys.

Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

Class 10. Surface coatings and surface phenomena.

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Electron micrographs.

Class 13. Results by unconventional techniques.

Class 14. Color prints in any of the above classes. (No transparencies accepted.)

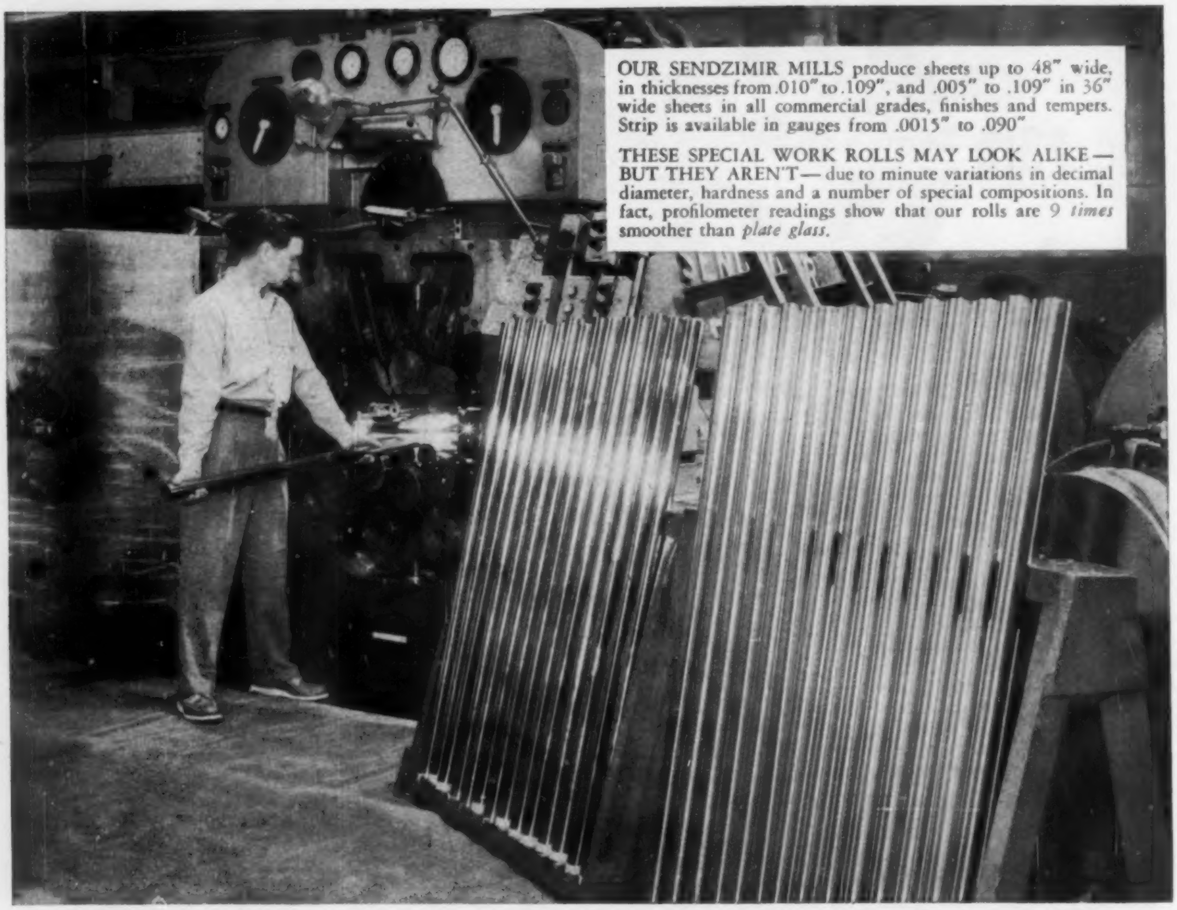
AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various ASM Chapters.

40th NATIONAL METAL CONGRESS & EXPOSITION

CLEVELAND PUBLIC AUDITORIUM — — — OCTOBER 27 THRU 31, 1958



It takes more than just a precision mill to produce STAINLESS STEEL *of MicroRold® quality*

. . . it takes Operating Know-How. Only Washington Steel, first to use Sendzimir sheet rolling, can offer you 10 years of practical experience with these mills.

Every hot-rolled stainless steel band has variations in thickness and surface characteristics which must be compensated for in the cold-reduction process to obtain precise gauge and flawless surfaces. To do this, special work rolls with minute diameter differences along the length of the roll are used in controlling such variations as crown, edge and camber. To accurately control all the possible variations requires a large number of these rolls, plus *highly skilled operators* who know from experience which rolls, speeds and reductions are required. These are but a few of important factors in quality rolling which can only be learned by *long* experience and association with precision mills.

Washington Steel is the only producer whose entire production stainless steel sheet and strip is rolled exclusively on the Sendzimir Mill.

WASHINGTON STEEL CORPORATION

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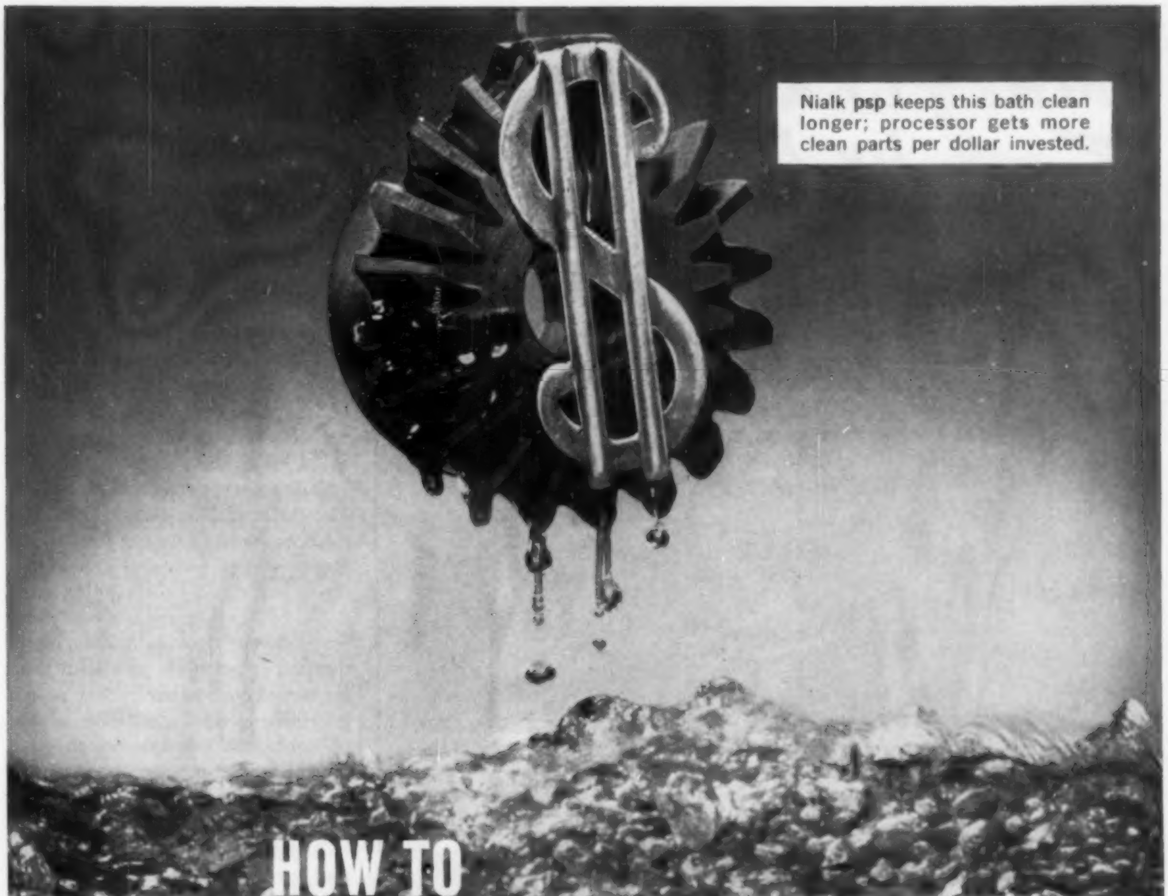

HOW TO MAKE YOUR $'s DEGREASE MORE PARTS

You make no profit on the time you spend cleaning out a degreaser.

You cut another slice off the top of profits whenever you have to add fresh stabilizer to your trichlorethylene bath.

When a bath goes "sour" while you're processing, you lose still more time and money.

psp is the simple answer

Trichlor is trichlor the world over; it's the *stabilizer* in your trichlor that can make the difference.

The difference in Nialk® stabilizer is *psp*—permanent staying power.

Nialk stabilizer is neutral. It cannot react with acids to form corrosive salts. Still it "accepts" acids and renders them completely harmless. The Nialk stabilizer will not stain or discolor your parts or allow your bath to become "sour."

You never add fresh stabilizer to a Nialk bath. The stabilizer stays potent no matter how long you use it. It's insoluble in water so you don't lose it during steam distillation or in the water separator of your degreaser.

Nialk frees your bath of those degradation products which settle on coils and cut down heat transfer. Cleanouts are widely spaced and quickly finished.

If your profit picture could use a little brightening, you'll want to know more about the whole subject of trichlor stabilizers. Send for our Bulletin 70 for the complete story.

HOOKER ELECTROCHEMICAL COMPANY
406 Union Street, Niagara Falls, N. Y.

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CHEMICALS
PLASTICS

DUREZ® PLASTICS DIVISION • NORTH TONAWANDA, N. Y.
NIALK® CHEMICALS • NIAGARA FALLS, N. Y.
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Sales Offices: Chicago, Ill.; Los Angeles, Calif.; New York, N. Y.; Niagara Falls, N. Y.; Philadelphia, Pa.; Tacoma, Wash.; Worcester, Mass. *In Canada:* Hooker Chemicals Limited, North Vancouver, B. C.

Radioactive Gases Used as Luminous Light Sources

Digest of "Commercial Markers Using Radioactive Gases", a summary of a talk by C. W. Wallhausen, presented at the 5th Annual Conference on Atomic Energy in Industry of the National Industrial Conference Board, Philadelphia, March 14-15, 1957.

Bright luminous light sources for use in signal lights, airport boundary markers, street markers, and airplane instrument panels have recently been made of calcined zinc sulfide phosphors excited by beta-emitting isotopes, such as strontium-90, thallium-204, promethium-147, and carbon-14, obtained from atomic-energy reactors. These isotopes, with half-lives ranging from 2.7 to 5000 years, are less costly and longer-lasting than the radium, mesothorium or polonium previously used for excitation. Moreover, they do not generally cause degradation of the phosphor, are more readily shielded to prevent the emission of penetrating primary radiation, and provide markers many times brighter.

A greater improvement in brightness can be attained with low toxicity by using certain beta-emitting gaseous isotopes for excitation of the phosphor. A gaseous isotope of this nature is safer to use than a solid one because if its container were broken the radiation-emitting substance would then be harmlessly diffused in the atmosphere. Krypton-85 and hydrogen-3 or tritium are gaseous isotopes that emit useful beta rays. The former emits a ray of higher energy, but requires shielding for gamma radiation. Both have half-lives of over ten years, and are available in high concentrations of energy. Large quantities of active material can be introduced with them into small volumes without danger of internal absorption of the radiation. Greater flexibility in design and simplicity in fabrication are attained with these activators.

A luminous marker using a radioactive gas activator is generally constructed as a sealed glass cell, although metal cells having sealed glass windows can also be used. The dry powdered phosphor can either be merely placed in the cell with the gas before sealing, or it

XXVII

This is the twenty-seventh of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steels: The Effect of Cold-Drawing

The cold-drawing of alloy bars was discussed in the advertisement prior to this one, No. XXVI in the series. Here, we continue with a general explanation of the effect of cold-drawing.

During the cold-drawing process, certain changes take place in the steel structure, and in mechanical properties. There is a slight increase in tensile strength, compared with a substantial increase in yield point, and a decrease in ductility. These properties enable the production of small parts which require the greater strength necessary for certain automatic-machine forming operations, and a machine finish superior to hot-rolled material. Naturally, the beneficial effects of alloy steels are attained in the subsequent heat-treatment of parts.

The process of cold-drawing results in bars which are free from scale, accurate to shape, and within close tolerances. These conditions are ideal for automatic machining, as the elimination of scale is conducive to long tool life, and the accuracy of shape and close tolerances permit the bars to pass freely through the feed mechanism of the "automatic." Moreover, the cold-drawn finish and tolerances may be such that machining can be eliminated in some areas of the finished part. For example, sparkplug shells are produced from hexagon bars which require no machining on the hexagon sections.

Continuous roller hearths and car-bottom furnaces of both standard and controlled-atmosphere types, are used for special treatment of alloy bars before cold-drawing. Thermal stress-relieving can be used to reduce residual stresses in the steel caused by the cold-drawing process, wherein the mechanical properties will be altered depending upon the temperature used.

If you would like more specific details about the chemical composition or mechanical properties of cold-drawn alloy bars, and the results that can be expected, by all means consult our technical staff. Bethlehem metallurgists will gladly help you work out any problem, without cost or obligation on your part.

In the next advertisement, No. XXVIII in this series, the second category in cold-finishing will be discussed, i. e., the turning and grinding of alloy steel bars.

Remember that Bethlehem produces a wide and complete range of cold-drawn alloy steel bars in rounds, hexagons, squares, or flats, in standard, odd, decimal or metric sizes required, as well as special sections. Bethlehem also makes the full range of AISI standard alloy steels, and special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I to No. XXVII, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 27 subjects in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY

BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Radioactive Gases . . .

can be applied as a thin coating on the inner surface of the cell. Reflectors can be arranged to improve the efficiency of the output of light. Compactness can be achieved if necessary by absorbing the tritium activator on a metallic foil, which is coated with a thin layer of phosphor and laminated between thin sheets of plastic for protection.

Light sources activated by krypton-85 or tritium have been prepared in all colors from blue through a deep orange-red. Greater surface brightness has been attained with yellow or green colors than with orange-red, though visibility of the latter compared favorably with that of the colors having higher brightness values.

George F. Comstock

Infiltration of Sintered Iron Compacts

Digest of "High-Strength Powdered Metal Parts", by Robert L. Pettibone, *Eaton Engineering Forum*, Vol. 18, No. 2, June 1957, p. 2-7.

Three types of sintering treatments are used in powdered metal fabrication. In the first and most common, the metal or alloy remains entirely in the solid state during the heat treatment. In the second, a liquid metal or alloy phase is present during the entire sintering cycle, and compacts are heterogeneous after sintering between the liquidus and solidus of the alloy system. The best known example of this method is cemented carbide, used for cutting tools and dies.

The third variation applies to alloys in which the liquid metal or alloy phase is formed during the actual sintering process, but disappears by diffusion and formation of a solid solution before the cycle is completed. Alloys are homogeneous following sintering. They include bronze bearings and commutator rings.

Greatest gains in physical properties are possible in the second variation which includes infiltration. In production of cemented carbides, sintering with a liquid phase results in a size change of 40 to 50%,

MOLY NEWS

CLIMAX MOLYBDENUM · DIVISION OF AMERICAN METAL CLIMAX, INC.

Climax Develops an Extremely Tough, Abrasion-resistant Chrome-Moly White Iron

New Alloy Proves Superior in Erosive Applications

A new martensitic white iron has proved exceptionally tough and resistant to abrasion. It's called Alloy 42. Its excellent combination of properties are related to its structure — which consists of hard chrome-moly carbides favorably distributed in a matrix of martensite plus retained austenite.

Tests indicate Alloy 42 is especially economical for parts subject to erosive wear: sand pumps, flotation impellers, sand classifier wear shoes, pug mill blades, brick mold liners and chute liners.

For example, heat-treated Alloy 42 impellers in a 5" sand pump handling coarsely ground taconite ore have already lasted over 1,000 hours. Previous impellers made of a 4.5% Ni, 1.5% Cr type of martensitic iron lasted only 350 to 400 hours.

Because of its toughness, Alloy 42 can also be used where moderate impacts would cause low alloy types of white iron to break or spall. And it may prove more economical than the soft rubber parts or linings now used in various abrasive applications. Its resistance to tearing by tramp coarse materials and chemical attacks by oils and other organic compounds is an obvious advantage.

The recommended composition range is: Carbon 3.00-3.50%; Silicon 0.30-0.60; Manganese 0.60-0.90; Chromium 15.0-18.0; Molybdenum 2.75-3.25.

A Climax bulletin on Alloy 42 discusses melting and casting, molds and shrinkage, heat treatment, structure, physical properties, machinability, welding and cutting. *For a free copy, circle #1 on the coupon.*

Heat Treating Improves the Wear Resistance of Gray Iron

Heat treating can improve many of the properties of gray iron, particularly resistance to wear. Wear resistance in quenched-and-tempered gray iron is many times greater than that of pearlitic irons. With cams and similar parts, hot quenching provides better wear resistance than quenching and hardening to the same hardness. Surface hardening is frequently selected for gray iron because it locally improves wear resistance with minimum distortion.

Why Moly Iron Bulletin #6 contains valuable information on surface hardening, annealing and stress-relieving molybdenum-alloyed irons. This bulletin gives examples of improvements obtained by heat treating gears, cable drums, pump-ring castings, tappets, valve guides and machine tool ways.

Flame hardening the teeth on a sprocket improves wear resistance with minimum distortion.

For a free copy of ***"Why Moly Iron Bulletin #6,"*** *circle #2 on the coupon.*

Tempering Low-Alloy Creep-Resistant Steels

A recent British paper discusses the roles of chromium, molybdenum and vanadium in low-alloy steels with high creep strength. The relation between creep properties, microstructure changes and carbide composition is given special attention.

For a copy of ***"The Tempering of Low-alloy Creep-resistant Steels Containing Chromium, Molybdenum and Vanadium"*** *by E. Smith and J. Nutting, circle #6.*

Moly Helps High Alloys Fight Corrosive Attacks

Highly alloyed materials are playing a greater part in combating corrosion. A current paper on these alloys considers the molybdenum-bearing alloys at length and also discusses cobalt-base alloys and silicon-bearing alloys.

For copies of this paper, ***"High Alloys to Combat Corrosion"*** *by E. D. Weisert, circle #7.*

Thermenol Shows Excellent Resistance to Heat, Corrosion

Thermenol, an iron-aluminum-molybdenum magnetic alloy, compares favorably with other high-temperature materials, and in some cases promises even better service. For unlike many alloys, it doesn't lose tensile strength rapidly up to 1200 F. It also has excellent resistance to oxidizing and sulfur-bearing atmospheres at high temperatures.

For a copy of ***"Iron-aluminum Magnetic Alloy Has Excellent Heat Resistance,"*** *circle #8.*

Moly in Nickel-base Casting Alloys Improves High Temperature Service

Molybdenum is helping at least two nickel-base alloys to work more effectively in high temperature applications. One of the alloys, with 5% Mo, combines good castability with very good creep strength at temperatures up to 1800 F (much better than that of moly-free alloys). The second, with 10% Mo, shows high resistance to thermal shock.

For free copies of ***"Some Properties of Nickel-base Casting Alloys for High-temperature Service"*** *by D. R. Wood and J. F. Gregg, circle #3.*

Cast Steels Studied at Low Temperatures

The British Steel Castings Research Association has completed new studies on the effect of melting practice, composition and treatment of steel castings. Five of the seven alloy steels investigated contained molybdenum. The benefits of using molybdenum in low alloy steel castings for low temperature service are clearly shown in comparisons of 1.5% Mn and 1.5% Mn-Mo.

For reprints of ***"The Low-temperature Impact Properties of Cast Steel"*** *by W. J. Jackson and G. M. Michie, circle #4.*

New Data Available on Low Carbon Bainitic Steels

Studies have been made on new steels based on boron-0.5% Mo. Tensile strengths up to 180,000 psi can now be obtained within the bainitic range with a wide range of cooling rates. Thus these low-carbon bainitic steels offer a good combination of mechanical properties as-rolled or as-air-cooled. These properties can be obtained in large sections because hardenability is high. Good welding properties and tempering characteristics make the steels especially suitable as high-strength weldable steels, forgings, die blocks, etc.

For copies of ***"Low-carbon Bainitic Steels"*** *by K. J. Irvine and F. B. Pickering, circle #5.*

Climax Molybdenum, Dept. 5
Division of American Metal Climax, Inc.
500 Fifth Avenue, New York 36, N. Y.

I'd like more information on:
1 2 3 4 5 6 7 8

Name________________

Company________________

Street________________

City________________ State________

Iron Compacts . . .

eventually requiring machining and grinding. Not so, however, with infiltration where any volume changes are under calculated control.

Basically, infiltration includes compressing and sintering iron or iron-carbon powder compositions, then placing a pressed but not sintered copper compact in close contact with the iron "skeleton." The two compacts pass through a controlled-atmosphere furnace at approximately copper brazing temperature. In this step, the copper melts and is drawn into the pores of the iron or steel compact by capillary action, thus bringing the infiltrated compact to full theoretical density.

The infiltrant is a vital key to the success of the process. Purity is relatively unimportant, but close contact with the skeleton compact and exact caluculated weight are paramount considerations. Too much copper leaves an excess on the surface of the skeleton which is most difficult to remove; too little results in "starve infiltration" which cuts down physical properties in transverse rupture, tensile, and impact.

Small density variations in the skeleton compact, usually established at either 75 or 85%, can lead to under or overinfiltration. One corrective is the addition of another element such as manganese to the infiltrant powder to supply material which will oxidize readily but will still retain its form and not infiltrate to the skeleton. Excess infiltrant thus is retained.

Solubility of iron in copper (3 to 5%) will cause some surface erosion at the spot where copper enters into the iron skeleton. This can be avoided by incorporating a small amount of iron powder in the infiltrant, or by providing a gate or riser on the skeleton at the point of contact. This projection later can be sawed or machined off readily.

The primary factor influencing physical properties of these compacts is failure to achieve complete infiltrated density. During the actual

Heat Treatments and Properties of Infiltrated Iron Powder Compacts

	Alloy		
	75-25, Fe-Cu	75-25, Fe-Cu	84-15-1, Fe-Cu-C
Annealing temperature	1500° F. slow cool	1500° F. slow cool	1500° F. slow cool
Heat treat temperature	950 4 hr., slow cool	1550 water quench	1500 water quench
Draw temperature	....	....	1050 1 hr.
Yield strength, psi.	35-40,000	85-90,000	115-125,000
Ult. strength, psi.	60-65,000	115-125,000	160-180,000
Elongation, %	20-25	7-10	4-6
Reduction of area, %	20-25	7-10	4-6
Rockwell B hardness	70-75	95-100	110-115

Iron Compacts . . .

infiltration cycle, a size change will occur in the part from the original skeleton size. Small amounts of carbon added to the skeleton material will control this change effectively, even to zero limits. Where tolerances less than ± 0.002 in. are specified, coining after infiltration is recommended, preceded, however, by annealing to reduce required press tonnages.

Results of physical tests on "as-infiltrated" compacts indicate that the cooling rate from the infiltration temperature controls the properties. To control erratic values, the heat treatments in the table on p. 206 are prescribed. The properties of 75-25, Fe-Cu material are altered substantially when heat treatment is changed from 950° F. for 4 hr. and slow cool, to 1550° F. and water quench. With the application of this "substitute" heat treatment, full range of properties can be obtained.

ARTHUR H. ALLEN

High-Temperature Stress-Corrosion of Titanium Alloys

Digest of "Progress Report on the Salt Corrosion of Titanium Alloys at Elevated Temperature and Stress", TML Report No. 88, Battelle Memorial Institute, Nov. 20, 1957, 41 p.

MOST APPLICATIONS of titanium and its alloys have been based upon the elevated-temperature properties of these materials. Their stress-stability has therefore been of critical importance, and the alloys have generally been placed in service only after annealing to achieve the most stable structure possible.

More recently certain alloys have been heat treated to achieve higher strengths, and tests have demonstrated adequate high-temperature service life.

Occasional stress-rupture tests have indicated early failure by intergranular cracking. Attempts to duplicate these failures were unsuccessful until it was observed that an unusual oxide in the crack zone had formed. This was subsequently traced to salt corrosion cracking, the salt having originated from finger-

Titanium . . .

prints in the specimen test zone. Extensive tests were subsequently made to determine the susceptibility of titanium and its alloys to elevated-temperature stress-corrosion cracking, and the results are presented in the present report.

The authors conclude that titanium alloys are subject to stress-corrosion cracking when in intimate contact with sodium chloride at temperatures above 500° F., and that certain oxides accelerate the attack. The data correlate well, and indicate threshhold combinations of stress and temperature below which the failure does not occur.

Possible preventive measures were evaluated, including cladding, shot-blasting, anodizing and combinations of these treatments. Among the most promising are glass-bead blasting, followed by sulphuric acid anodizing.

Titanium jet engine ring components were tested under operating conditions with salt coatings applied. Failure within 2 hr. was observed under certain conditions, indicative of the criticality of salt content in the operating medium. Various tests led to the following conclusions:

1. Alloy titanium components in J-57 and J-75 engines in service operate at safe temperatures and stress levels.

2. Severity of cracking is related to the amount of salt present.

3. Susceptibility to stress-corrosion attack decreases with increasing air velocity.

4. The combination glass-bead blasting and anodizing affords protection for higher temperature and stress levels in moving air.

James L. Wyatt

UNICHROME
Trade Mark

News about

COATINGS for METALS

Metallic..........Organic..........Decorative..........Protective

Cracking eliminated as cause of chromium failure

Crack-free Chromium beats corrosion, wear, thermal shock

These typical applications show how users are taking advantage of the unique properties of these chromium deposits:

- In hydraulic power steering for autos, Industrial Crack-Free Chromium on shafts protects against corrosion and wear, prevents the leakage past seals which occurred with ordinary chromium.
- On rocket engine parts, Industrial Crack-Free Chromium overcomes cracking and corrosion at high temperatures, resists gas erosion that had worn away best steels and other electrodeposits.
- Most major manufacturers of washing machines now specify Industrial Crack-Free Chromium on steel drive shafts. It improves corrosion resistance, reduces wear.
- Service life of cutting and drilling tools increased 300 to 400% when company switched to Industrial Crack-Free Chromium from ordinary chromium process.
- With Bright Crack-Free Chromium, a leading automotive producer has substantially increased corrosion resistance of plated steel and die cast parts, especially those frequently exposed to salt air and snow-melting chemicals.

METAL & THERMIT 1908 1958 50TH YEAR

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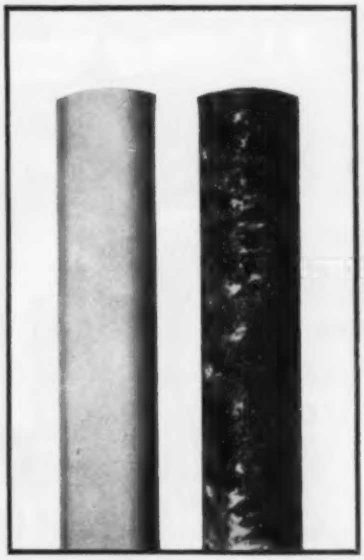
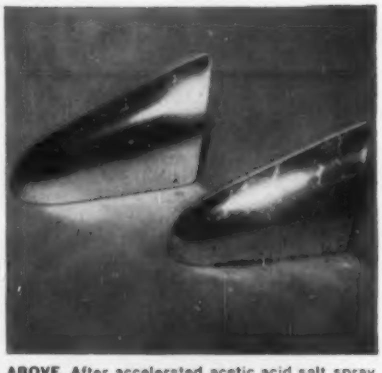




ABOVE. After accelerated acetic acid salt spray 72 hours: Top — Bright Crack-Free Chromium, 75 millionths of inch; Bottom — Ordinary Chromium, 20 millionths of inch; both over .001" nickel and .0005" copper on steel.

LEFT. Steel shaft on right, with 0.0005 inch of ordinary chromium, showed rust over entire surface after 100-hour salt spray test. Shaft at left, with 0.0005 inch of Crack-Free Chromium, was virtually unaffected in same test.

It is well known that ordinary chromium plate suffers from a network of fine cracks . . . an open invitation for corrosives to reach and corrode the basis metal. Now proved too, is the fact that Unichrome Crack-Free Chromium can overcome this shortcoming of ordinary chromium. Deposits stay sound as thickness builds up. The process delivers unimpaired all the inherent corrosion resistance of chromium metal.

FUNCTIONAL, MATTE DEPOSITS

For engineering applications, Industrial Crack-Free Chromium gives a matte finish. It can be used decoratively, too, either "as plated," or after a wheel operation to produce a satin, bright or combination finish. This ductile chromium is solving many corrosion and wear problems on such varied items as hydraulic rams, power steering shafts, washing machine and typewriter parts, high temperature molds, rocket engine parts. In one application, .0009" of Crack-Free Chromium stopped metallic corrosion as well as leakage of aqueous hydraulic fluid, where .003 to .005" of ordinary chromium failed.

A BETTER BRIGHT PLATE

Unichrome Crack-Free Chromium can also be deposited bright directly, with no need for buffing. Unlike ordinary chromium, Bright Crack-Free Chromium *reinforces* the corrosion resistance of the undercoats. Tested under extremely severe exposures, it has demonstrated that a major improvement in durable decorative chromium plating is now possible.

Crack-Free Chromium baths are of the self-regulating type. They simplify control problems, and maintain key chemical ingredients in optimum balance for highest quality plating. Send for Bulletins.

Famous Heroult Furnace redesigned . . .

to help you keep down the cost of

Would you like to have an enlarged copy of this detail drawing? We'll be glad to send you one without obligation if you will send in the coupon on opposite page.

We welcome **an opportunity to help you select and install the Heroult Furnace best suited to your requirements. Remember—*the Heroult we make and install for you will be the finest electric melting furnace that money can buy!***

electric furnace steel

To HELP YOU PRODUCE better quality steel faster and more economically, we have made important design improvements in the long-famous Heroult Electric Melting Furnace. Five of the features shown in the cutaway drawing at the left and described below are to be found *only* in the new Heroult. *All ten* of the illustrated features are important to those interested in the most modern melting equipment. Any way you look at it—performance efficiency, operating economy, or low-cost maintenance—this *new* Heroult is unquestionably the *finest* electric melting furnace on the market.

1. The Heroult Furnace is *the only* 100% *mechanically operated electric furnace.*

It includes such mechanical features as: (A) heavy rack-and-pinion-type tilting mechanism, (B) mechanical roof lift, (C) motor-driven, rotating, jib-type roof swing, (D) winch-operated, water-cooled, jib-type door-lifting mechanism, and (E) high-speed, electro-mechanical electrode-positioning mechanism.

2. *Another exclusive* — Cage-type shell construction with shell plates loosely attached (F) to a heavy supporting structure.

This construction minimizes shell warping and allows easy replacement of damaged shell plates.

3. *Exclusive* — Operating mechanism independently supported.

The tilting platform on which all operating mechanisms are supported is attached directly to the rockers independent of the shell structure (G). Thus operating mechanisms are unaffected by any shell distortion.

4. *Exclusive*—Flat Bottom Shell.

This feature (H) facilitates easy shell relining and provides maximum protection against burnouts. Thicker refractory at the sides of the hearth promotes more uniform bath temperature.

5. *Exclusive* — Water-cooled, Skew Back Roof Ring.

This feature (I) eliminates the need for special skew-shaped roof refractories.

6. Electrode Mast Safety Device.

This spring-loaded, rack-and-pawl-type device (J) provides positive protection against damage resulting from electrode winch cable breakage.

7. Square-Section, Water-Cooled Electrode Mast Arms.

This design (K) guarantees a rigid connection between mast and mast arm, thus helping to maintain proper electrode position.

8. Remote-Controlled Electrode Clamps.

This device, of the spring-clamp, air-release type, is located inside of the rear section of the water-cooled mast arm where heat cannot affect it.

9. Square-Sectioned Electrode Mast.

This design feature (L), developed by American Bridge, assures proper guiding and electrode positioning.

10. Rockers.

The heavy fabricated steel curved top and bottom rockers (M) minimize forward travel during tilting. These rockers are so designed that the furnace will tend to return to horizontal position from any degree of tilt.

THE NEW

Heroult

ELECTRIC FURNACES

are available in:

—sizes of shell diameter ranging from 7′ 0″ up, and with capacities of from 6,000 lbs. up to 400,000 lbs. and greater. They are equipped with roof-removing mechanism to permit fast top charging. They can readily be furnished with a non-magnetic shell bottom section to accommodate induction-stirring equipment.

Gantry-type top-charge furnaces, door-charge furnaces, and special furnaces for duplexing and non-ferrous melting can also be supplied.

Heroult

ELECTRIC MELTING FURNACES

Send coupon for catalog and/or enlarged copy of detail drawing with special installation and engineering data.

American Bridge Division
525 William Penn Place, Dept MP-68
Pittsburgh 30, Pa.

Please send me a copy of the latest Heroult Electric Furnace catalog ( ) and/or your new folder showing large drawing with special installation and engineering data ( ).

Name .... Title ....

Firm Name ....

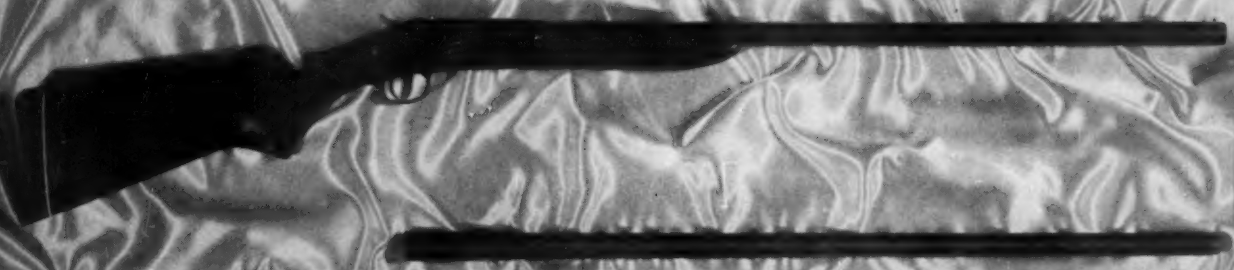
Address ....

City .... State ....

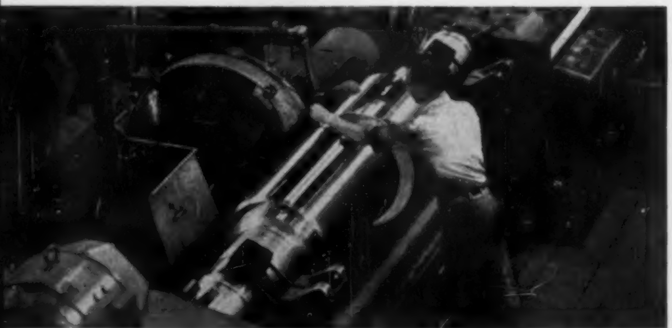
American Bridge
Division of USS United States Steel

Contracting Offices in New York, Philadelphia, Chicago, San Francisco, and other principal cities. United States Steel Export Company, New York

PROOF OF QUALITY



REPUBLIC COLD DRAWN CARBON BARS are used in the manufacture of Shotgun Barrels by Harrington and Richardson, Inc. Mr. Arthur F. Hird, Chief Engineer, states his reasons in a letter reproduced on the opposite page. For information on how Republic Cold Finished Steel may help solve your manufacturing problems, contact your local Republic office or mail coupon.



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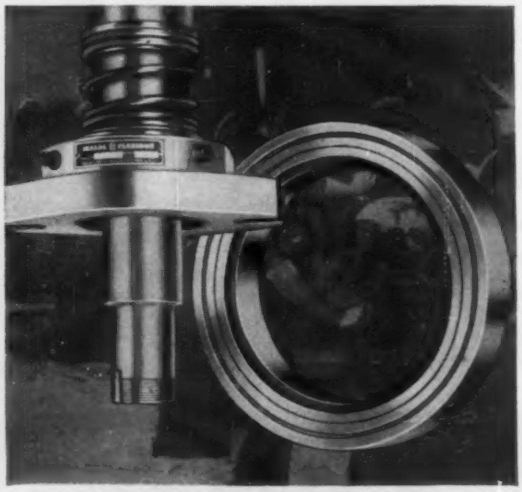

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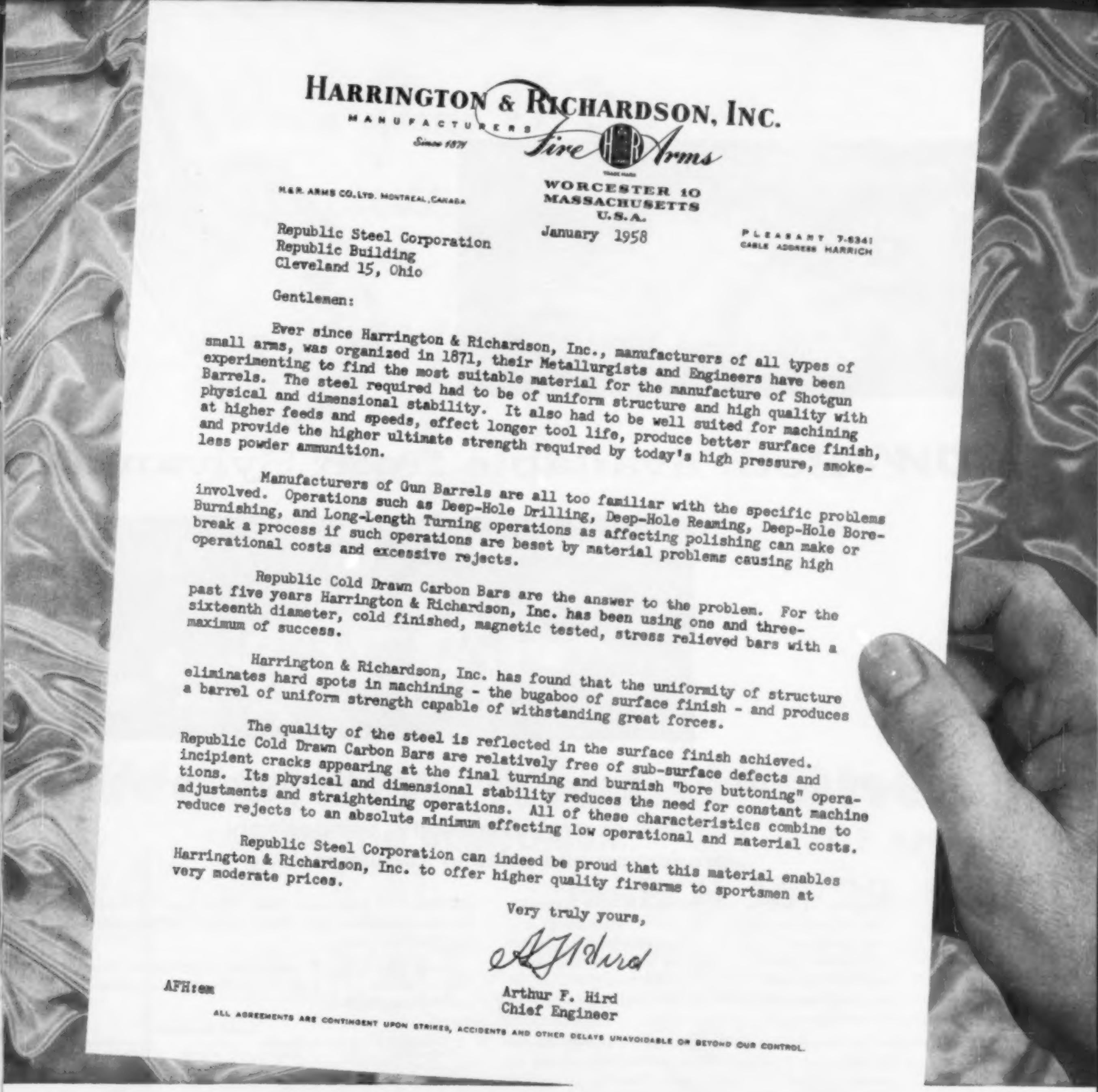

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Gentlemen:

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Manufacturers of Gun Barrels are all too familiar with the specific problems involved. Operations such as Deep-Hole Drilling, Deep-Hole Reaming, Deep-Hole Bore-Burnishing, and Long-Length Turning operations as affecting polishing can make or break a process if such operations are beset by material problems causing high operational costs and excessive rejects.

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Harrington & Richardson, Inc. has found that the uniformity of structure eliminates hard spots in machining - the bugaboo of surface finish - and produces a barrel of uniform strength capable of withstanding great forces.

The quality of the steel is reflected in the surface finish achieved. Republic Cold Drawn Carbon Bars are relatively free of sub-surface defects and incipient cracks appearing at the final turning and burnish "bore buttoning" operations. Its physical and dimensional stability reduces the need for constant machine adjustments and straightening operations. All of these characteristics combine to reduce rejects to an absolute minimum effecting low operational and material costs.

Republic Steel Corporation can indeed be proud that this material enables Harrington & Richardson, Inc. to offer higher quality firearms to sportsmen at very moderate prices.

Very truly yours,

A J Hird

Arthur F. Hird
Chief Engineer

AFH:em

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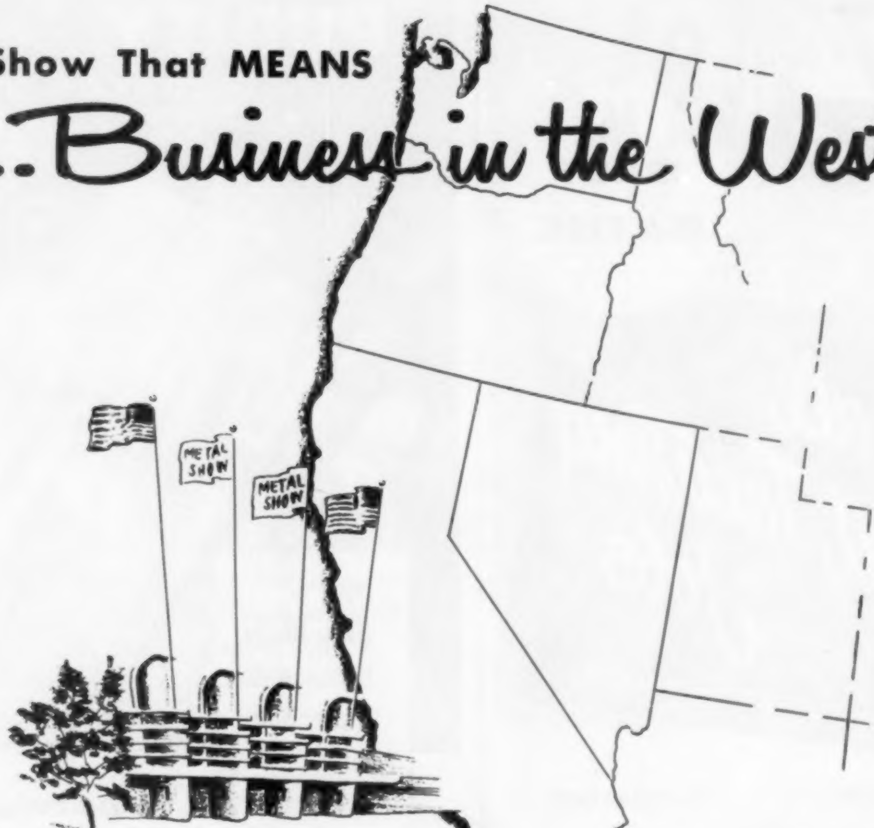

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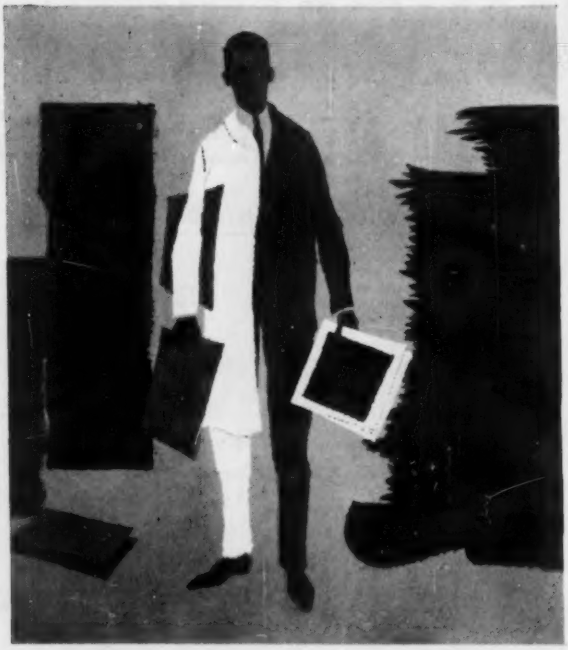

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Sub-Zero	SZH653	6.5	−85° F.	−75° F.	60"	28"	42¾"	47"	15"	16"
Sub-Zero	SZHC657	6.5	−140° F.	−125° F.	60"	28"	42¾"	47"	15"	16"
Rivet Cooler	RSZ503	5.0	−30° F.	−20° F.	42"	28"	41"	30"	16"	18"

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Edited by G. William Zuspan
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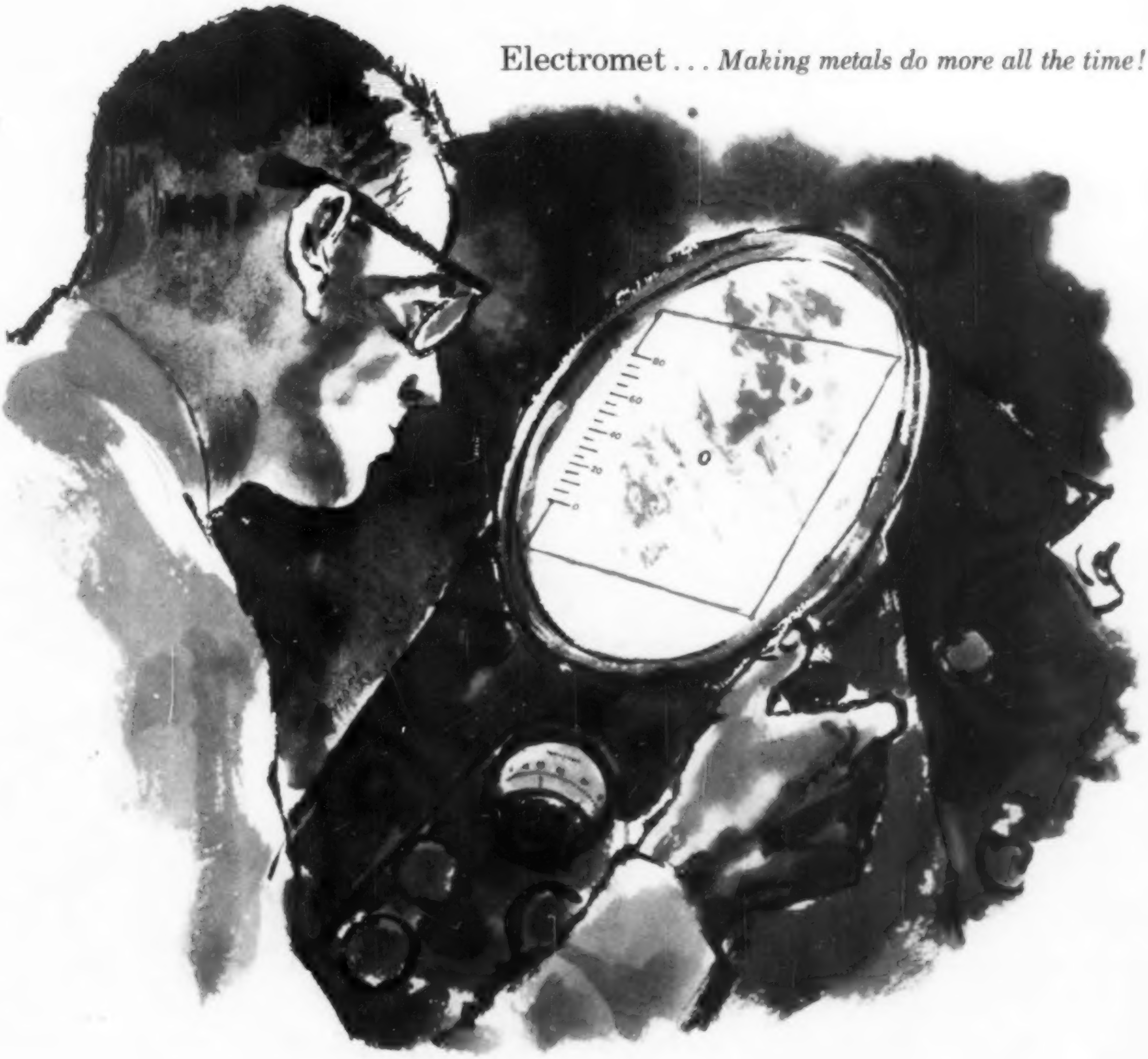

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